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ABSTRACT

This document consists of four units (chapters) focusing on evolution (chapter I), civilization of man (chapter II), ecological concepts (chapter III), and limnological concepts (Chapter IV). Each chapter contains "text material" on the topic indicated. In addition: (1) a list of key vocabulary words, questions, reading list, and questions related to the reading are provided for chapter I; (2) objectives, list of key vocabulary words, questions, and reading list are provided for chapter II; and (3) a bibliography, tests, and laboratory/field investigations are provided for the six areas covered in chapter IV (historical aspects; biological productivity; geology of lake morphometry; water chemistry; biotic communities; and physical parameters). (JN)

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ENVIRONMENTAL STUDIES

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Class Notes
by
Stephen L. Canipe, Ed.D.

SE 038 585

TABLE OF CONTENTS

Unit I.....1

Unit II.....16

Unit III.....34

Unit IV.....69

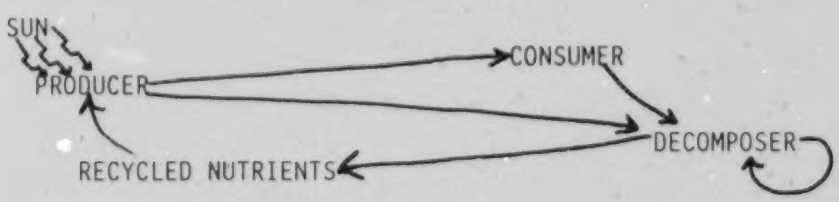
Exam. 108

Labs. 121

UNIT I - EVOLUTION

"History is only a record of crimes and misfortunes."
--Voltaire

The earth has often been compared to a spaceship. This comparison is very apt since, like a spaceship, all necessities of life and all waste products must be carried along with the voyagers. Unlike a spaceship the earth has a limited ability to cleanse itself through the cyclic properties of matter flow. The flow is shown in figure A-1.



[A-1] Matter Flow (highly diagramatic)

This scheme is very simple in principle but highly complicated in practice. As can be guessed, the physical part of the earth sets limits on what the biological faction can do. For example if an organism is aquatic, the availability of water will seriously affect its distribution. An organism that eats only a certain food, will of necessity, be found where that food is available. A plant that needs a particular inset to pollinate its flowers will be found only where the insect can also survive. The idea is not which is of the most importance, it is rather how these facets interact. No change in plant or animal occurs without changes in the surroundings. These changes occur very slowly. The term that is generally applied to this type of slow change is evolution.

According to Darwin this is a process of adaptation and survival of the fittest. It cannot be emphasized too often that organisms do not change in order to survive, but rather they survive because they have changed. In other words the changes that are occurring have a selective value for the species.

There are innumerable examples in the palentologic records of such occurrences. We shall look at a few briefly. One very obvious event which took place in the life scheme on Earth was when the amphibians first walked on the land. If we think back toward the beginning of time, we find the earth covered with broad expanses of water. There are innumerable type of organisms that inhabit the water sphere. They are as varied as the blades of grass on a lawn. We look at the land and see plants and insects but try as we might there are no animals which we can detect that have a backbone. Wait.... there is a movement....as we zoom closer and closer there appears to be a fish "walking" from one pool to another. We withdraw a discrete distance to watch. Soon we see that other fish should have also moved because the smaller of the ponds is drying up and the heat of the noonday sun will soon cause the water to completely disappear. As we continue to watch our fish, we see that it is behaving less and less like a fish. It comes out of the water for extended periods..it moves haltingly over the land..but it moves! Its skin is moist as it carries a thin layer of water around with it.....but it is an air-breathing vertebrate!

Why did it leave the safety of the water to try its luck on the broad expanse of dry terrain? Certainly not because it decided to. Since certain changes had occurred in the throat of this creature it did not perish when the climate of the earth began to change and get drier. Those organisms which had the ability to survive without the continual water bath did; those

without died. Thus environmental change had caused the land vertebrate that had first started walking on the land to be selected for.

Other environmental influences can be seen as we find the earth's climate changing again. This time instead of drying up, waters were merely diverted as the land went through an uplifting which eventually formed the Appalachians to form. As water became harder to get the selection pressure was for those that could survive in increasingly xeric climates.

Another environmental factor that affects evolution was the cooling of the atmosphere. This cooling gave DOMINANCE to those animals which were homiothermic. The poikilothermic organisms declined because the cool-blooded ones didn't have the necessary traits for continued dominance even though they continue to survive to the present day.

Our evolutionary patterns would not be complete without some mention of nature's supreme creature. The environmental factors which caused the development of this superior being are as obscure as its evolutionary history. The environment has affected furhter development and thse evidences are blatantly obvious even to the most callous observer.

Homo sapiens, nature's supreme, is nothing more than a generalized mess of vessels, skin bones, and muscles. The only highly organized part of the body is the brain and nervous system. What ever forced this awesome biped from its arboreal pleasures caused a selective process to begin that has continued until the present day. When the generalized man stopped upon the ground the selection of the better adjusted man began. That man which was the most generalized was the one that tended to survive. Had the humanoids that were man's precursors been highly developed it is likely that you would not be reading this. You would either be swinging back and forth through the trees loosing raucous screams or be buried and turned to store in

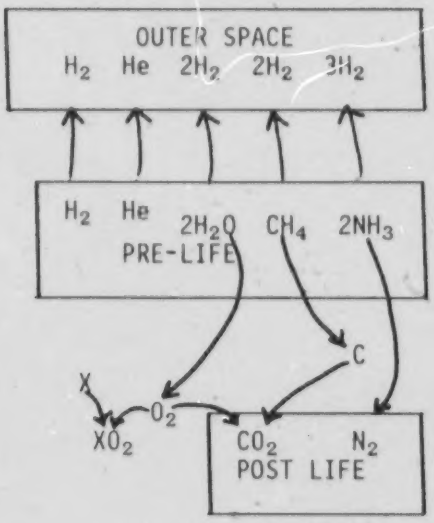
nature's garbage pile. These two alternatives were avoided so that now man is not only plotting his destiny but also charting his past.

Since man originated from the earth he is bound to it in many ways. The same ideas that have been mentioned in evolution affect all creatures are also affecting man. he is neither above nor below animals and plants---he is one with them.

Before considering how man got to the position that he presently occupies, it is first necessary to discuss plausible ideas for the creation of the earth. It should be understood that no definitive answer can be given since one does not exist. Explanations are arrived at so that man with his unsatiable curiosity has some stepping stones for his mental climbing.

Probably the best explanations of the earth's creation is in the idea of clouds of galactic gas or dust. This cloud coalesced into several bodies in the general assocaition that is today known as our solar system. This scenario does not explain where the dust came from, how the sun started fusion, etc. But remember -- this is just a stairstep not the summit. D. L. Gilbert (1965) came up with an astonishing conclusion-"life on Earth is purely accidental." Gilbert's ideas are graphically shown in figures A-2 and A-3.

From these it is obvious that biological entities are not necessary to cause the succession of the earth from a reducing to an oxidizing place. They may help in this process but are not required. Many people have tried to explain this origin of life on Earth, all explanations require great time spans which make them incomprehensible to humans. One of the best analogies was developed by James C. Rettie and printed in Coronet magazine in 196=51. A brief excerpt follow:



[A-2]

	RELATIVE ABUNDANCE % atoms cosmos	biosphere
H	86.68	62.6
He	13.18	0.0
O	0.09	24.9
C	0.03	10.6
N	0.01	1.1
other	0.01	0.8

[A-3]

The Physiologist 8:9-34, 1965.

Imagine that you are watching a film of the last 757 million years of the Earth's past. The film will begin at midnight on New Year's Eve and will run without interruption until midnight of the next New Year's Eve.

Throughout January, February, and March the movie runs on without showing any signs of life on earth. Then in early April, single-celled organisms appear; many-celled ones later in April. Late in May come the first vertebrates. In the middle of July the first land plants appear. In late August the first amphibians appear; reptiles come by the middle of September. Dinosaurs dominate the scene through the rest of September, October, and much of November. Meanwhile the first birds and mammals appear. The raising of the Rocky Mountains near the end of November signals the end of the reptilian domination. As December rolls by, we see mammals becoming dominant. As Christmas arrives the Colorado begins to cut its way through the Grand Canyon. Suddenly about noon of 31 December the first man appears. During the afternoon the glaciers push southward and recede four times. By 11 o'clock in the evening "OLd Stone Age Man" are apparent; 11:45 sees men who make refined stone tools and till the soil. Five or six minutes before the end of the picture, civilization appears. One minute and seventeen seconds before the end the Christian era begins. Twenty seconds before the end Columbus discovers America. Seven seconds before the end the Declaration of Independence is signed.....

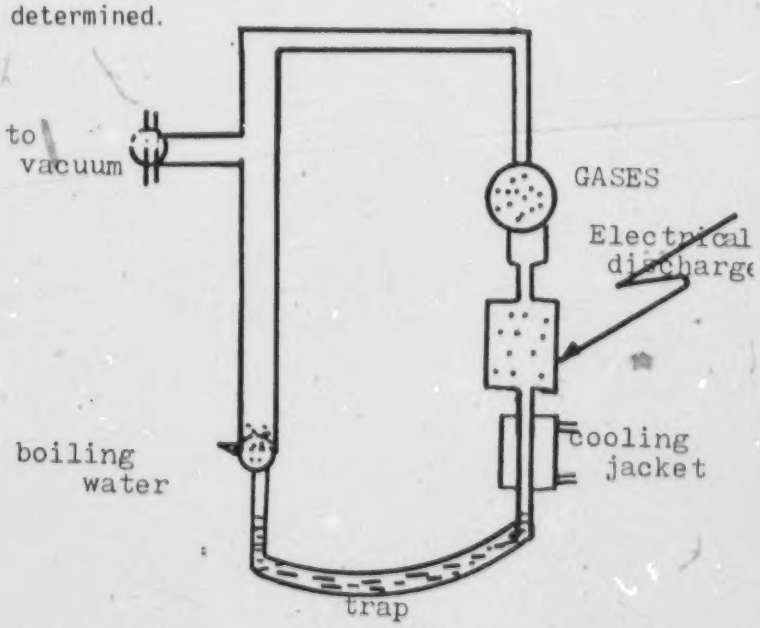
Thus: life has existed for some eight months; man has been here about 12 hours of one day; dinosaurs dominated for 70 days-man for about half of a day; he has had civilization for only 5 or 6 minutes of that time.

Thus the progress of man has been exceedingly swift in comparison with the time that he has been on the Earth.

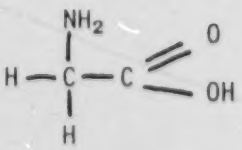
Rettie, Coronet, March, 1951.

With this time scale in mind two experiments as to possible origins of life can be postulated. Both of the experimental schemes are based at least partially on the 1932 ideas of a Russian scientist, OPARIN. His was the first attempt to tie physical history to the origin of life. Two Americans, Urey and Miller, did the first definitive test of Oparin's ideas. They placed in an apparatus (A-4) various gases which evidence indicated were in the primeval atmosphere of Earth (CH_4, NH_3, H_2O, H_2). An electrical spark was added and discovered in the trap were several α amino acids among them glycine. The alpha (α) acids have a great biological significance, the exact reason has not been determined.

[A-4] Urev-Miller Apparatus



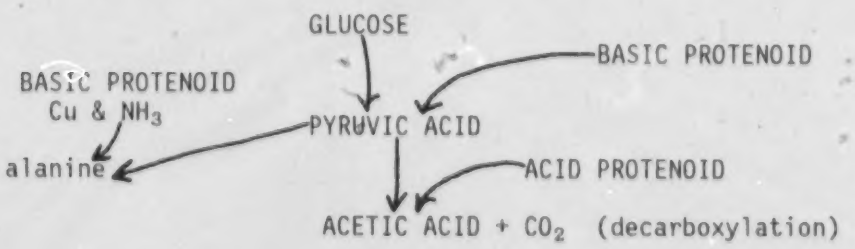
[A-5] Alpha amino acid



This is termed an alpha amino acid because the NH_3 (amine) is on the carbon next to the alpha or carboxyl (COOH) carbon.

It is still a far step from amine acids to organized protoplasm. If one looks at the time involved, the seas of the Earth must have become a veritable broth of organic molecules with all sorts of combinations possible. This condition could not exist today because of the existence of the decomposers (A-1). But before life was here the chance combinations could be expected to occur. (Reading from the Scientific American, August, 1954, "Origins of Life.")

Another experiment was carried out by Fox and is reported in Naturwissenschaften 56: 1-9, 1969, "Self-ordered Polymers and Propogative Cell-like Systems." Fox took the Urey-Miller experiment and enlarged upon it. He said if amino acids are present then one might reasonably expect their anhydrides to also be present. An anhydride is a form where water is lost (generally by heating). Fox took 18 anhydrides placed them together and found that they coalesced to form bodies which he called proteinoids. It was found that the proteinoids did not exhibit a Gaussian (bell-shaped) distribution. Fox termed this anomaly First Order of Assembly--his tenent being the nature of the polymer structure is derived from the nature of the component monomers. Some of these aggregated protenoids could break down glucose (i.e., they acted as an enzyme). This scheme is illustrated in A-6.



[A-6] Metabolic-like activity in First Order Self-Assembly

Fox also found that the protenoids arranged themselves into a bileaflet configuration and that if glucose, fructose, starch, and glycogen are inside the microsphere after several hours only starch and glycogen remain inside indicating a selectively permeable activity is taking place. This phenomenon is termed Second Order Self Assembly.

After these experiments Fox took some microspheres (protenoids) and stained them. After 1-2 weeks many of the spheres had developed buds. The buds were also stained. After the buds have separated, they then form unstained buds. Thus, there was an aggregation of new material. Fox termed this the Third Order Assembly.

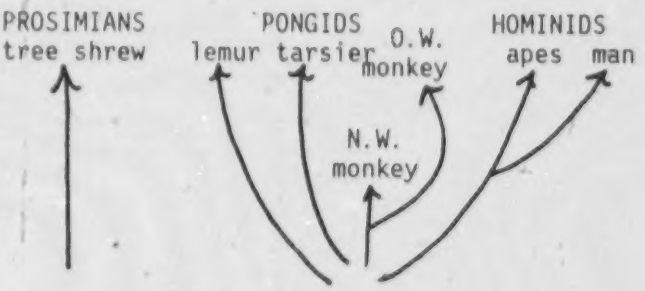
To summarize the work of Fox, he first discovered a preferential choice of amino acids that were to form the proteinoids; he showed enzyme-like activity; he showed the selectively permeable activity; and finally he demonstrated reproduction from new material. This work must be held in prospective since Fox set out with definite things that he wanted to prove--this biased his results. At the same time be necessary to explain the origin of life with a naturalistic theory.

However, life originated it is here and the next step to consider is how evolution took place. There are four main ideas of evolutionary pathways. These are shown graphically in A-7. For further discussion of general evolutionary principles the reader is referred to any good elementary biology test.

[A-7] Schemes of Evolution

The particular evolutionary pathway that any reader will be most interested in is the one which leads to man. Biologists have chosen to call the group of organisms to which man belongs the primates. A-8 shows a postulated scheme of primate evolution.

EPOCH	YEARS B.P.
Recent	less than 10000
Pleistocene	11,000
Pliocene	1,000,000
Miocene	13,000,000
Oligocene	25,000,000
Eocene	36,000,000
Paleocene	58,000,000



[A-8] Primate Evolution

Primates are interesting in that they have developed along omniverous lines. Since primates eat both meat and vegetable matter it might be informative to observe the carnivores and the herbivores to see if any similarities can be found. The carnivore has a very definite home base--that is an area where, eventhough he travels far afield, he ultimately returns. The female carnivore typically stays close to this home base, the male being the wanderer. The herbivores are nomadic without a definite home base; the females and the young must, of necessity, accompany the group. Territoriality is highly developed in carnivores and a defense of territory is thought by some (Ardrey) to be more important than defense of sexual rights. The carnivore marks his area in various ways--the most common pattern is seen even in the domesticated dog and various objects-fire hydrants, poles, trees, legs of strangers, etc. It has been noted that in most cases this "staked-out" territory is held inviolate by other area carnivores. One naturalist working with Canadian wolves in the field found that if he marked his territory the wolves didn't enter. Herbivores have

little if any territorial instinct but typically live gregariously in a developed social structure. This structure is called a peck order. Peck-order can be defined as a social system which ranks individuals in that society. It is noted that carnivores display great teamwork to attain their food--a pack of wolves, a pride of lions are good examples. Herbivores display little cooperation; they are much more competitive for their positions in the heirarchy of the peck order.

Food of carnivores is by definition high in protein. The scarcity or uncertainty of meals is assuaged by gorgings. The lion is a prime example- a meal every 3 days is enough. The boa can go without food for months without deleterious effects. Herbivores must have continuous meals since little of what is eaten can be stored. Much of the energy necessary for maintaining the herbivore is expended, paradoxically enough, in looking for food. This in turn is used to provide energy to look for more food, etc.

Logic dictates that a carnivore have well-developed senses. Herbivores must also have acute senses for survival. The differences in the two lies in the type of vision-carnivores have a type which makes it easy for them to detect motion while herbivore's vision is mostly to determine the texture of things. Also because of life modes it would be expected that carnivores have a strong, running physique while herbivores might have an agile one.

An interesting ritual has been assigned to carnivores, the <u>feces ritual</u>. Because the carnivore doesn't move about it is necessary to avoid fouling its den. This ritual developed probably by accident but natural selection saw to it that the trait might develop evolutionarily. Some Victorian scholars have suggested that it was for esthetic reasons that the ritual came about and judging from the smell of the totally proteinaceous diet excreta this might even have some validity!! Herbivores never bother

to leave their place of sleep to delicate; after all they will have a new home tomorrow. If there are similarities to man seen in the above descriptions they may be either accidental or purposeful. Further study is indicated.

Another interesting and important concept is the theory of neotony. Scientists first became aware of an anomalous situation in considering the salamander in South America. It was seen that this organism became sexually mature while still otherwise physically immature. Study showed that if hormone treatments were given then a infantile precosiousness did not occur. This research opened an entire area of thought concerning man's development, particularily man's brain. Most primates are born with their brain nearly complete, for example monkeys have 70% of their adult-size brain when they are born, the rest coming within one year. Man at birth has only 23% of the adult brain and it takes over 22 years to attain the full growth. The brain is not the only aspect which supports a neotonistic origin for man; others are position of the head, long slender neck, flat face, small teeth, absence of a brow ridge. These are inconclusive taken separately but when viewed together they are almost irrefutable proof of some neotony in man.

The idea of infantilism has opened up areas of thought about how this biological structure led to various social structures. A scenario might be helpful--a young one is born and is helpless, only continual care by the mother allows survival. The mother, however, must employ herself with food-gathering or starve. The female will require help and most logically this help would come from her mate. As a direct result of neotony a pair bond would result thus helping to cause a differentiation of the sex roles. Pair bonds allow many problems to be solved--males and females had to fall in love and remain faithful otherwise virle males wouldn't want to go off

and leave their females. This cooperation of the men was necessary to sustain the social structure that was beginning. This trust allowed a reduction of serious sexual rivalries between males. The biggest benefit was to offspring who had two parents to care for their needs.

Mankind's entire sexual evolution has been based upon the pair bond (chapter 1, Naked Ape). To summarize briefly there are three phases of sexual behavior--pair - formation, pre-copulatory, copulatory. This progression is from public to private sectors. The reading from Morris will amplify these ideas.

Now that mankind is here he reflects upon his origins. No definite answer has been found but a series of articles that were printed in Scientific American, September, 1960 gives some insight. Thse are also available as offprints and in book form.

ACTIVITIES CHAPTER I

1. Divide a line graph according to Rettie's scheme of time.
2. Enlarge the matter flow into some type of a complex food web (use at least 10 organisms).
3. If you could choose any three organisms to accompany you on a spaceship, what would they be and why?
4. Can you rationalize, to yourself, the naturalistic idea of primate evolution and the Biblical account? How?
5. Choose five (5) persons (describe if not generally known) that you feel exemplify life.

TERMS TO KNOW

1. evolution
2. adaptation
3. selective value
4. palentologic
5. xeric
6. dominance
7. Homiothermic
8. poikilothermic
9. blatantly
10. callous
11. precursors
12. racous
13. plausible
14. unsatible
15. coalesced
16. scenario
17. postulated
18. amino acid
19. propogative
20. anhydride
21. proteinoids
22. selective permeability
23. divergent
24. convergent
25. reticulate
26. omniverous
27. territorality
28. peck order
29. assuaged
30. deleterious
31. paradoxically
32. feces ritual
33. esthetic
34. anomalous
34. copulation

QUESTIONS

1. How is the Earth like a spaceship?
2. Generally describe evolution.
3. Why should having warm blood help an organism survive?
4. What allowed a generalized man to survive where a specialized one could not?
5. What are the ultimate implications of Gilbert's ideas?
6. Why is it hard for us to visualize large time spans?
7. How did Oparin pave the way for the Urey-Miller Hypothesis?
8. Do you feel that Fox introduced bias in his experiments? Why?
9. What is the significance of Fox's work ignoring bias?
10. Of what significance is the schemes of evolution to any living being today?
11. How does man fit into the comparison of herbivores and carnivores?
12. What is the significance of NEOTONY to man?

READINGS

"Origin of Life," Wald, George
"Origin of Society," Sahlins, M.D.
"Origin of Speech," Hockett, Charles F.
"Tools and Human Evolution," Washburn, Sherwood L.
"ORIGINS" Chapter 1 of The Naked Ape, Morris, Desmond

COLLATERAL READING QUESTIONS

Origin of Life

1. What is the importance of the experiments to disprove spontaneous generation?
2. Why is the "impossible probable?"
3. Can you describe the Urey-Miller experiment?
4. How does the idea of chemical equilibrium help or hurt the naturalistic theory?
5. What were the energy sources of early life?
6. Are we alone in the universe? Why?

Origin of Society

1. How do we draw conclusions about our beginnings?
2. What is the weak point in this approach?
3. Human societies differs from other primate societies--How? What is the significance?
4. What was the value of "year-round" sex?
5. What role did sex play in cultural evolution?
6. How has the idea of kinship-marriage helped in our social evolution?
7. How has marriage been used to secure peace?
8. Compare kinship-friendship economics to the economic man.

Origins of Speech

1. What would be your comment to a member of the Languistic Society of Paris after their ruling? Why?
2. What are the purposes of the design features?
3. What are the sets which belong to the protohomonids?
4. What is the value in communication?

Tools and Human Evolution

1. What were the effects of tools on man's evolution?
2. What is the relationship between pelvic evolution and man's total evolution?
3. What are the implications of a human pelvis as far as hunting?
4. What are the ramifications of the disappearance of the canines?
5. What evidence exists that points to the fact that man's domestication has changed out cranium?
6. What are the comparative differences in a man's cortical areas and those of an ape?
7. How have humans adapted the conditions of conception and child delivery to their life mode.

Origins

From this reading you should always be looking for review points as well as any new thing that you can see.

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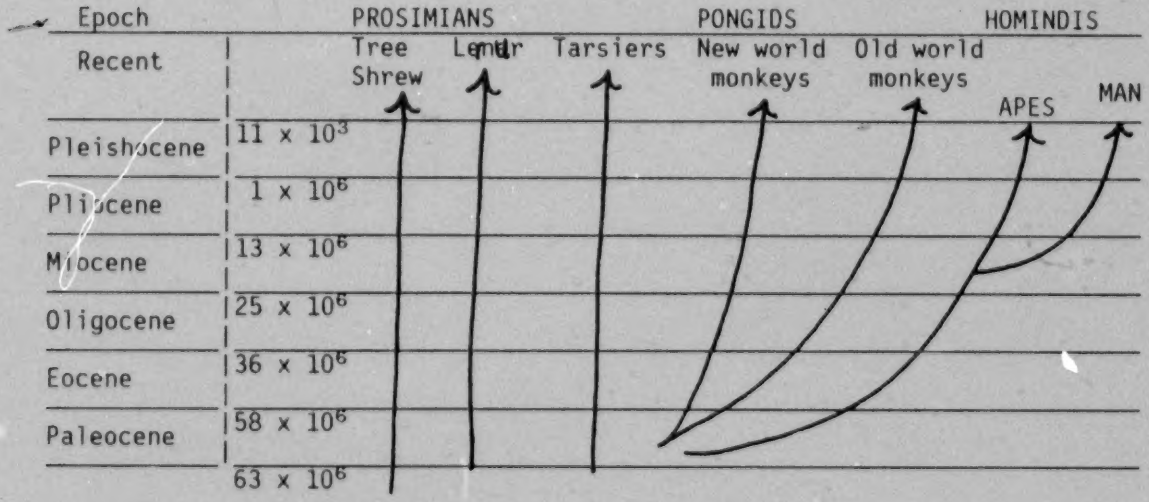
ENVIRONMENTAL STUDIES (EVOLUTION)
STUDY QUESTIONS

A. "Tools and Human Evolution," Scientific American, September, 1960.

1. What were the effects of tools on man's evolution?
2. What is the relationship between pelvic evolution and man's total evolution?
3. What are the implications of a "human" pelvis as far as hunting is concerned?
4. What are the ramifications of the disappearance of large canire teeth?
5. What evidence exists which indicates man's "domestication" has changed man's cranium?
6. What comparative differences exist between a man's and an ape's cortical areas?
7. How have humans adapted the conditions of conception and child delivery to their life mode?

B. Questions for Quiz (Three -3- will be selected from the following)

1. Describe the complex cyclic nature of matter and also be able to describe the role that ENTROPY has in the cycle.
2. Using either yarrow, grasses, or frogs be able to describe the effect that the environment can have on species formation.
3. Be able to explain the modern theory of evolution as it relates to specific organisms (q.v. man, kangroo, koala, etc.).
4. Be able to draw and describe the four types of evolutionary mechanisms.
5. Be able to describe the evolution of the primates and also know generally the geologic time periods when these took place.
6. What are the effects of erect posture on the development of the brain?
7. What relationships exist between tool use and human evolution?
8. What was the role of sex in social group formation?
9. What was the role of speech in cultural development?
10. Compare man to pure herbivores and pure carnivores as described by Morris.



UNIT II - CIVILIZATION OF MAN

"In the dust where we have buried the silent races and their abominations we have buried so much of the delicate magic of life."

D. H. Lawrence

There are certain physical needs that can not be denied, man's settlements tended to show these. It is unusual, indeed, to find settlements where the rainfall fell below a certain level (usually 10"-20"/year). Water either lotic or lentic was a major criterion in sites settlements. Enough water was a necessity of life and it is important in choosing a homesite outside the urban areas water is still a very important criterion in the selection of a place to live. Temperature also had to fall within certain norms. Basically this is outlining the theory of the origin of the state. Much of the material comes from Rober L. Carneiro, curator of the American Museum of Natural History in New York.

Carneiro's theory revolves around the idea he calls "CIRCUMSCRIPTION." There are several facets to his theory one environmental circumscription. His examples are the Nile, Tigris-Euphrates and Indus River Valleys and the Valley of Mexico, and the coastal valleys of Peru. He believes that all have one thing in common and that is that each has some good agricultural land that is circumscribed by some harsh barrier. Some of these and others will be described later in this chapter. Dr. Carneiro believes that his theory can best be understood trhough the comparison of two groups of people one that is circumscribed and one that is not. He chose in an article that was written for Science magazine 21 August 1970, to compare the Xinga from the Upper Xinga valley of the Amazon and the Indians of the coastal valleys

of Peru who were to later become the Incas. To point out a few of these comparisons--the Xinga are spread out over a rather large area of the Amazon River valley; their villages are 10-15 miles apart, with this distance separating villages there is little conflict involved with their mobile agricultural patterns. Warfare was a frequent visitor among the tribes. It did not however have as a consequence the banishment of the loser from the conquered land. Land was not typically the reason for fighting. The most common reasons were for personal prestige, the capture of women, revenge, etc. Eventhough the reason for fighting was not land often the vanquished tribe would move far back into the jungle. Not because the land had been taken but rather to escape the fighting that had occurred and might occur again. This move was easily accomplished because the population was scarce enough that the move did not interfer with another tribe. The consequence of this warfare"...was to disperse villages over a wide area, and to keep them autonomous."

Widely contrasting with the Xinga are the Peruvian coastal valleys. There is no abundance of land easily accessible; the natural boundaries are severe--oceans, mountains, deserts. Carnerio admits that his reconstruction is based on inference but believes that the evidence is available that supports his ideas. Villages tend to grow in size a common result of marriage and child birth. There is likewise a tendency for the villages to fragment as growth occurs. This splitting could occur as long as there was land that was available for the splinter groups to occupy. In the approximately 80 valleys that make up the coast of Peru the number of villages grow faster that the increase in the population of the villages. Soon all readily aerable land was under the plow. This occurrence necessitated changes so that agricultural output was increased through

intensified farming of present land and the tilling of heretofor unused land through the use of terracing and irrigation techniques. New aerable land could not be produced fast enough to allay the need for land by the population pressure. Thus warfare among the villages broke out for a reason that was unknown in the Amazon Valley -- LAND. The increase in the population and the demands of the humans had changed war from its basic purpose of revenge.

As the cause of wars became more and more economic the frequency intensity, and importance of them increased. At this juncture a tribe that lost a war to a neighbor was in sad straits--there was no place to migrate since all aerable land had already been taken. There were several options that were open to the conquerer 1) expulsion (meaning that the tribe that had just been defeated must fight again) 2) extermination or 3) political subjugation. Subjugation meant that the conquered tribe must pay a tribute to the victor. Usually this payment took the form of food. Also there was a chance tht the defeated village might become a satellite of the victor. These larger incorporated villages in turn fought each other with the same consequences that were mentioned in the village vs. village. This led to a greater and greater pressure and eventually the entire valley was under the rule of one large village. This meant of course that the village form of government had been transcended and now the chiefdom was the major form. A logical extension is that the valleys now fought each other with the strongest valley subjugating the others. This has led to the formation of multivalley Kingdoms. These in turn fought and finally the Incan Empire was born.

This discussion is generally how Carneiro sees environmental circumscription as leading to the state. He also believes that

circumscription can work through resource concentration--the mechanics are much the same except that instead of there being severe limiting factors there was just a more advantageous position when compared to a lesser one. A fuller discussion of the details are to be found in his article in Science. Also in this article is a fuller discussion of the third idea or circumscription that of social circumscription. This idea is shown in his discussion of the Yanomamo. He states that the villages near the center of the tribal area behave differently that those round the periphery.

At this point is should be stated that the idea of circumscription is not without its critics or opponents. Perhaps a brief discussion of some of the other theories might be helpful in ascertaining the vagarities in the theories. Theories fall into two main categories I. voluntaristic; II. coercive. (fig. B-1) The voluntaristic theories all have as a basic premise

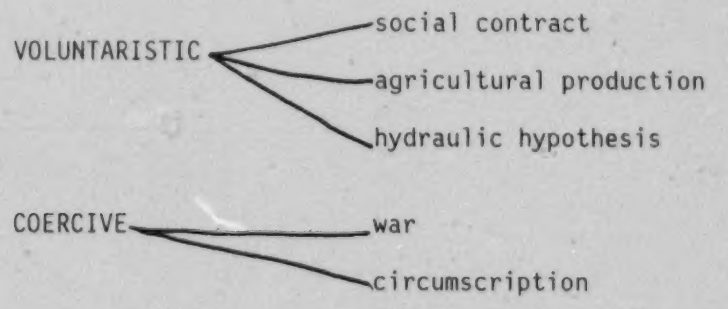


Fig. B-1. Sample chart of the heirarchy of the theories. SLC

that people voluntarily at some point gave up their independence and merged into a collective unit called the state. The social contract originally proposed by Rosseau states that for reasons unnamed the people decided to band together. The mostly widely accepted voluntary theory is the idea of agricultural surpluses. These surpluses arose more of less spontaneously allowing a division of labor and therefore specialization, political

integration and advancement to a state. The late V. Gordon Childe, a British archeologist was an ardent believer in this theory. Karl Wittfogel proposed the "hydraulic hypothesis." This briefly states that where irrigation was needed the people banded together and therefore became the origin of the state.

The coercive theories all believe that force and not enlightened self-interest is the process whereby autonomous villages evolve into large political units. War as a force was proposed by Hercilitus about twenty-five hundred years ago, Herbert Spencer, somewhat more contemporary also believes that war was a prime mover in state development. Circumscription advocates fully admit that war is important but they believe that is only a mechanism and circumscription is more indicative of the rise of the state.

Whatever the reason for the rise of the state changes once begun have proceded rapidly in a type of geometric ratio. It is a safe assumption that mankind is no longer totally at the whims of his environmental condition but is now in many ways a co-maker of his destiny. A brief review of some other cultures right show circumscription a bit clearer. It is the belief of this author that at the present moment this is the only theory capable of handling the mountains of information that is available to study the beginnings of civilization.

For years it has been known that the lay of the land, the amount of rainfall, rivers, etc. have an effect on the development of civilizations. Looking at three ancient civilizations several similarities should be obvious.

To understand the development of the Egyptian civilization it is first of all important to know what was happening in that area from a geological sense. The Sahara area was not yet a desert; but is beginning to dry up.

Finally a stage was reached where the natives had to make a choice they could stay and fight the rigors of the Sahara or they could migrate into the Nile River Valley. The valley at this time was no lush magnet that was drawing the people it was on the contrary very forbidding place that was a jungle. The ancient Egyptians opted for the Nile about 11,000 B.C. (13,000 B.P.).

The taming of the jungle necessitated that men work together in fairly large groups. This group interaction led to political development. This political development in turn led to economic development. This it is seen that the environment by forcing the people into the river valley and then by causing them to work together for the common good gave rise to that Egyptian civilization.

It might be argued and feasibly so that the groups that cleared the land in the Nile jungle were not united into a state at the time of clearing and that the clearing process itself gave rise to severe competition. This was pointed out earlier in the discussion of the Peruvian coastal valleys. Only later was Egypt united into a strong state.

The Egyptian power base was agricultural. This was dependent upon still another environmental factor, the flooding of the Nile River. So regular was the Nile that calendars were set up with the floods as a basis. As with any river that forms a delta region as the delta enlarges the flood power of the river diminishes. The erratic flooding which took place caused the erosion of the Egyptian power ant the eventual downfall. Many authorities also believe that the Nile in these later years had good periods and bad ones. During the good ones the strongest of the Egyptians Pharos were in power.

The conquering armies of Alexander the Great might have arrived sooner had it not been for the great natural boundaries Egypt found herself endowed. Thus the cause of Egypts circumscription the Sahara was a two-fold friend--it gave the country civilization and it protected Egypt from enemies.

In Mesopotamia the story is a bit different. As in Egypt the civilization was basically agrarian. The economy was also dependent on the flooding of rivers (Tigris-Euphrates). The differences between the civilizations are important to note while Egypt was highly isolated and protected by natural boundaries, Mesopotamia found itself blessed with none of these things. Mesopotamia was open to constant attacks by maurauding nomads. Also while the Nile flooded regularly the Tigris and Euphrates were not so accommodating. They flooded at irregular intervals thus not only depositing salt over the sometimes ripe crops but also causing the death of some of the populace. The Nile was basically a straight river the Trigris and Euphrates were meandering rivers, meaning that they moved back and forth in their banks sometimes changing the entire course of the river. This meandering left the readily aerable land in a limited quantity leading to a resource circumscription. This meandering also led to the formation of large marshy areas. It was in those marshes that the mosquitos would develop that would be part of the downfall of the Sumarian civilization (Mesopotamia).

In Mesopotamia there were several detrimental environmental factors at work 1) irregular flooding 2) meandering river, 3) no natural boundaries. All of these factors wroking in concert with others led to the decline. It is ironic that the same factors should lead to the rise and the decline of the empire.

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Greece was a country seemingly little different than most unendowed areas. There appeared to be little if any environmental gifts. The country was small, the land hilly, the soil rocky, the coastline irregular. But it was these very things acting in concert which caused the ascendency of the Greek Golden Age. The separateness of the people led to the development of the city states. Power basically evolved around two super-powerful city states--Athens and Sparta. The Spartans occupied the only large cultivatable land area in all of Greece--the Plain of Laconia. They were therefore not compelled to trade as they could grow most of the foodstuffs needed. The Athenians on the other hand had to trade to survive. They were able to use the seaways as their fields and thus developed a strong anvy in opposition to Sparta's strong army. The trade caused the Athenian culture to flourish. Indeed today when we think about Greek culture we are often thinking about the culture of Athens.

One very unfortunate item about the Greeks was the fact that internal communication was very difficult and it hardly ever took place. The reason was geographic barriers in the form of mountains that ran North and South across the country making intercourse with other city states difficult if not impossible.

Greece, therefore, developed her environmental conditions to give her what she desired. It gave sustenance to the Greek ideals that today we are proud to claim as part of our heritage. Without the hostile environment the Greek city state might never have developed and the formation Western civilization might have been seriously hampered.

As man's level of competition with other states increased environmental competition also increased, thus increasing the complexities of his everyday life. His whole cultural development put him into roles that he had no

biological preparation for. They were alien to his genes. He was forced to live in cities (an outgrowth of circumscription).

This city or urban living forced many changes upon the expanded family groups. Before he had known all the people with whom he came into daily contact. Now in the city they could be nothing but strangers to him. He could no longer relate he felt alienated. The obvious question "Why urbanize?" Urbanization was a direct result of the agricultural revolution. When man was a good gatherer, he was unable to live in large groups because of the scarcity of food. The advent of farming gave him the ability to group and to specialize.

Farming developed in three divergent areas; common factors link all these areas. Each is blessed by being climatologically mild, each is blessed with a natural grass, in addition they fulfill the idea of circumscription discussed earlier in this chapter. In the Mediterranean area there was wild wheat and wild barley; in Southern Asia there was wild rice; in Central American there was wild maize (corn). In each of these areas there grew up civilizations which were operating on a agricultural power base. The cities that were spawned didn't arise overnight, they came about through slow growth especially at first. After their beginnings they spread rapidly. The oldest known city is in Jericho and is about 8000 years old.

As the cities developed slowly so did trade between and among cities. There was no basis for trust among strangers the basic kindship-friendship economic system was being broken. There was no feeling of sameness among the city livers. Economics had to be based on something of value--crops, silver, beads, etc. Thus our present economic system was born. Eventually the barriers to outside trade toppled mainly because the city had grown too

large and lacked the diversity to continue to be self-sufficient. Trade resulted and later conquest, thus early on mankind began the economics of domination. These same ideas led to Japan's attack in World War II and was also a prime mover in Hitler's plans for Europe.

Man's coldblooded calculations about his fellowman is viewed by some with great horror. But in reality the people who behave badly toward others do not know them they are strangers. So what if we kill a few Viet Cong they do not belong to our group our tribe (our country). That our relationships have become for the most part impersonal and bloody is readily understood because unknown humans are not really of our "kind." Humans are communal lot needing interpersonal interaction. Cities are not conducive to these needs. Desmond Morris writing in the HUMAN ZOO refers to our cities as supertribes. He also asserts that supertribes can have superleaders who if not benevolent can lead to exhaggerated tyranny, despotism, and dictatorships.

These superleaders must have a wide following to be effective. This following was readily available because man tried to form smaller groups within this supertribe. Evidence exists when we look at ethnic areas of our cities and even to the cliquishness of our social and professional groups. We even isolate criminals in an imposed fashion that is we group them. Why do we act in these ways?

Environmental determinism has been used to explain much. Several theorist have tried to explain America's greatness and our democratic development through this method. Fredrick Jackson Turner had a Western Thesis, much of which is now in disrepute, but parts of which may be valuable to Americans as they examine their origins. Environmental determinism???

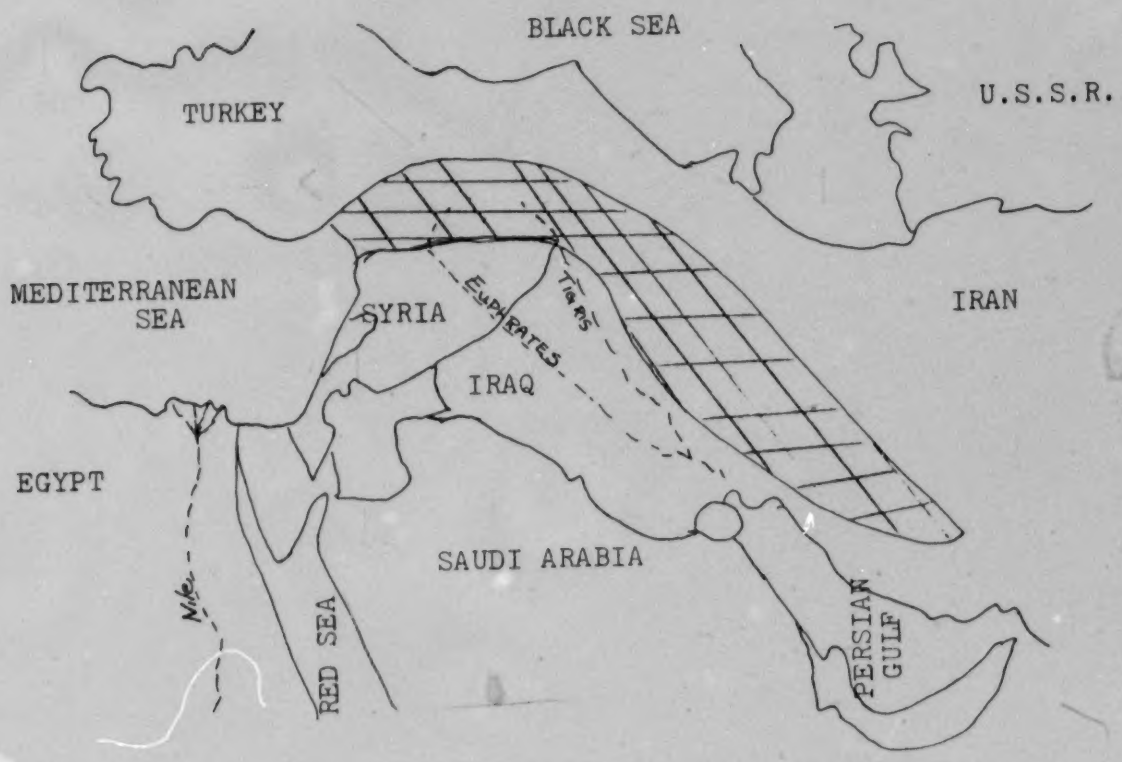

Fig. B-2. Map of the Fertile Cresent area

According to Turner the frontier ended as a line in 1880. The frontier may be defined as that place which causes a reversion to primitive social conditions. The moving of the frontier gave persons a change to change at each movement. When man attacks a frontier, he must modify to meet the new demands of the place or be conquered by the new area. Our frontier lines have changes several times in our short history as a nation. During the 17th Century the "fall line" was our frontier; in the 18th Century the line had moved to the Alleghenies; the Mississippi River became our frontier

during the first quarter of the 19th Century; the second quarter of the 19th Century saw the Missouri as our frontier; out present and last frontier other that space is the western mountains and the arid lands of the West and Alaska.

Turner had a formula to tell in what stage of development the frontier was. The earliest frontier existed when only a buffalo trail led from water hole to water water hole. Following the buffalo came the traders who brought their wares to ply them to the native Indians. Following on the heels of the traders were the ranchers who wanted huge tracts of land so that their cattle could grow. The last step in the changing frontier was the farmer, he destroyed the native vegetation and supplanted them with his own type of weeds. Native animals were forced further and further away.

Only a bit of thought is required to be directed to the idea of why the Indians were so upset with the farmers. This type of person in their homeland led to the demise of the type of life that the Indian had known. It might be helpful to consider the various frontier levels and their impact.

1) the buffalo being part of the natural scene did little to harm the way of life of the Indian, indeed they were necessary for its continued existence.
2) the trader was different, he brought goods and tales the likes of which the Indians had never seen or heard. Several of the tribes began procuring guns and alcohol from traders. Traders did little to directly upset the balance of nature.
3) when the ranchers came the Indian saw a slight threat to his existence. But not many ranchers could occupy the same area and

the Indian extracted his toll by taking a cow now and then. it was basically a peacful coexistence.

4) the farmer, however, could not exist in peace with the Indian or with nature. The reason for this being that the native crops and animals had to be destroyed to make room for the domesticated variety. Of course the Indian considered this a direct threat to their well being. With their guns they attacked the "white-eyes" in an attempt to drive them out of the land.

To look at the two major groups of immigrants, English and French and to view their varying troubles is really to check the type of frontier that each set up. The French originally came as traders with little of no colonization. Basically the French who came were only males with little need or inclination to set up either ranching or farming. The Indians therefore welcomed them and their tales of faraway places. The English on the other hand brought wives, children, and household goods. Clearing of land and planting of crops were all pastimes that the Indian saw as a threat to his well being so he attacked. In America then the basic difference between the French and English was not their language but the type of frontier that was set up by each group; the French with trading and the English with farming.

Turner saw several beneficial effects of the harshness of the frontier 1) ability to survive in the forest; 2) Indian style of fighting; and 3) cooperative spirit which is basic to any successful campaign.

Critics of Turner's thesis attack his ideas along several in roads. They accuse him of discounting "leap-frogging" settlements. The entrance of huge numbers of immigrants into the Ohio Valley in the late 19th Century, the skipping of middle America in the trip west in the 1949 Gold Rush.

Turner also implied that the frontier was a molder of institutions. Saying that civilizations would change under adverse conditions was tantamount to saying that the environment can grasp institution and rend it asunder. This according to the critics was too much to expect of nature.

If Turner's thesis be accepted how do we explain internal migrations. At certain levels of development the frontier line would regard others coming in as threats. The question is poorly answered by either Turner or his advocates.

One ohter major thought that Turner failed to expound upon and that is what about other colonial migrations like in Canada, South America, and the Orient? Can we say that the frontier is truly an American idea?

Another fault that is ascribed to the thesis is the multiplicity of meanings that he ascribes to the word frontier. At times the meaning is geographical or natural and at others the moral connotations are placed upon the word.

According to Turner an American was most American when he was least civilized. These Americans who had most completely divested themselves of the trappings of European civilizations were the most American.

Turner has several good ideas in his thesis. One is indeed changed by his environment but it cannot logically be argued that the environment has totally shaped one's being. The theory is partially correct but partially incorrect. It cannot be rejected in totality because some parts have no longer the great validity that Turner thought.

Environmental determinism and environmental circumscription and most likely responsible for the early development of ancient civilizations. The United States development came at a time that circumscription was not really applicable as there was already a state formed.

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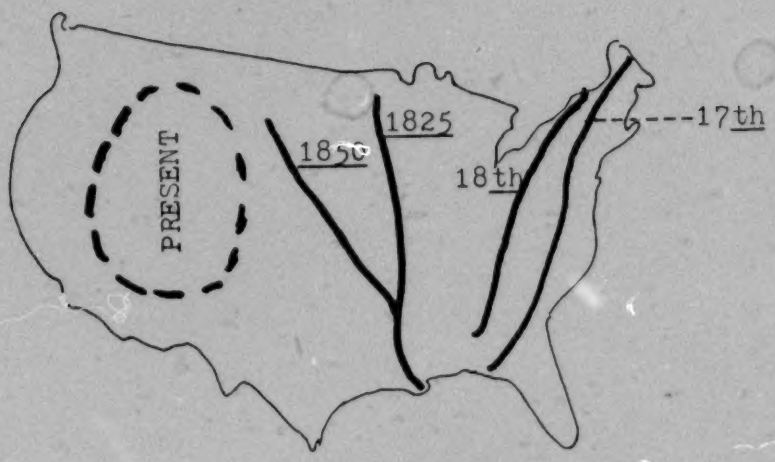

Fig. B-3. Map showing the frontier lines according to Turner.

Eventhough the United States government may not have been directly influenced by circumscription there are instances of lesser influence. One of these influences is through the Indian. Stuart Udall writing in the QUIET CRISIS points out that our inevitable conflict should have been forseen since settlers believed in owning the land and the Indian believed in jointly held property. The idea of circumscription can be seen here since the Europeans came from an area where land was held by individuals; this individual ownership an outgrowth of scarcity of land. The Indians were a neolithic people that had few if any land problems, this is not to say that they did not have strong ties to the land it simply states that the land was abundant. They held the land in great respect it was their Mother and they her sons. It is sometimes for present day Americans to understand this idea. It must have been equally hard for the Indian to understand the

idea of buying land. it could be used by individuals but to own--that was a totally alien concept. Tecumseh aptly stated the sentiments of most tribes when he said, "Sell the country?...why not sell the air the clouds, the great sea?"

President James Monroe gave the classical answer of a man of the times when he said, "The hunter or savage state requires a greater extent of land to sustain itself than is compatible with progress and the just claims of civilized life...and must yield to it." Thus from an official point of view we get the common saying of the time "the only good Indian is a dead Indian." It is perhaps ironic that today's back to nature movement should be reverting to those truths that the Indian knew long ago, not only knew but practiced for years Ironic indeed that we should now try to preserve that which a few short years ago we tried to destroy. Fickle man!

CHAPTER II

OBJECTIVES:

1. Using a man of an island or other hypothetical land decide (in groups) where you would settle and be prepared to defend your choice.

2. Research any four of the following: Xinga, Yanomamo, Inas, Cherokee, Sioux, Eskimo, ancient Egyptians, Greeks, Sumarians. Pay particular attention to environmental influences. Write a short theme and list your sources.

3. Choose a tribe of Plains Indians and try to discover if circumscription influenced their culture. Write a theme on your discovery and list your sources.

4. Research one or more of the voluntaristic theories. In outline form present to the class the findings. List sources.

5. Prepare a visual display (art, clipped pictures, photos, slices, etc.) to illustrate this chapter as if you would if it were going to the published. Each picture should be captioned so that its purpose is clear. Twenty should be used for clarity. A limit of 40 is expected

6. Read and report on the Human Zoo by Desmond Morris. Its significance to the chapter should be included. The report should be written and handed out to the students who have not read it.

7. Investigate the western Thesis and prepare a short debate for presentation to the class. Total time should be limited to 20 minutes. Have your sources available for inspection.

8. Using world maps show the following rainfall, temperature, population, major lakes and rivers. These should be placed on a poster and put up in the classroom.

9. Read Carnerio's article in Science and report to the class.

WORDS:

1. [illegible]erable
2. autonomous
3. circumscription
4. coercive
5. facet
6. lentic
7. lotic
8. voluntaristic

QUESTIONS:

1. List some of the physical needs for settlement.

2. How do the Xinga display environmental circumscription?

3. How do the coastal valleys of Peru fit into the theory of circumscription?

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4. Why was land so important to the Peru Indians?

5. List and describe the voluntaristic theories.

6. List and describe the coercive theories.

7. What is a power base and how does the term apply to Greece, Egypt, Mesopotamia, and the United States?

8. How could a meandering river wreck civilization?

9. Greece had what limits to its civilization? What did this lead to in Greece?

10. What were the effects of city living on primitive people?

11. What did Frederick J. Turner believe about the frontier?

12. List the various types of frontiers. List the frontier lines.

13. What were the traits that were engendered by the frontier?

14. How did the Indians view the land?

15. How is the present conservation movement tied to the land?

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UNIT III - ECOLOGICAL CONCEPTS

"We have met the enemy, and he is us." -- Unknown

When the topic of ecology comes up almost everyone these days considers this to be the same as pollution. Nothing could be further from the truth. Ecology is the basis of all the hue and cry but it is not the cause. To understand the place of pollution in the world it is very necessary that ecological concepts be well understood.

Ecology is a word which indicates the study of the surroundings. Many persons have worked in the ecological field. To attempt to name all the important men would be time-consuming and of little value since the real illuminaries in the field are still contemporary. This indicates an extremely young science, one which is still growing--growth pains are not uncommon, as the wrong track is pursued and then changed and pursued some more.

Most, but by no means all, of today's authorities in the field are convinced that an energy flow procedure represents the best way to come to an understanding of ecology. Energy flow is, without a doubt, a most (if not the most) important concept. This chapter has been arranged so that those with little basic ecological knowledge can build their expertise while those with knowledge already can gain deeper insights.

There is a heirarchy in the study of ecology that goes

INDIVIDUAL-----SPECIES-----POPULATION-----COMMUNITY-----ECOSYSTEM---
---BIOSPHERE.

Discussions of the "individual" would encompass the detailed study made of the billions upon billions of living organisms. Each one is a unique individual. Obviously this is beyond the realm of feasibility. Also unfeasible is the discussion of species since there are over 2,000,000 species of extent animals not to mention protists and plants. The biosphere is the conglomerate of all groups on earth and is too large to conveniently comprehend. It is the middle three--Population---Community---Ecosystem--that can be easily studies and easily understood.

An in-depth study of population will be undertaken in the chapter on human population. The basic ideas of population develop a fuller appreciation of the role that population plays in ecological contexts.

The four most important population determinants are natality, mortality, immigration, and emigration. Natality, or birth rate, is a positive influence on population. The addition of offspring may be slow like humans and elephants or rapid like bacteria. Two factors affect natality; one is litter size and the other is gestation period. The term litter size is not the most accurate term but carries the meaning well. Planners for the future really concern themselves with the parameter.

Mortality, another important determinent, is defined as death rate. Rather obviously death rates have a negative effect on the population. In studying death rates generally the figures are expressed in some number per 1000 or 100,000 population. This is done in order that the larger numbers involved render thetstatistical probabilities more accurate. The most interested persons in this parameter are the life insurance companies. There are large sets of actuarial tables giving the probabilities of death of a person at a particular age in a particular job. These probabilities are translated into a rate schedule for insurance.

A third determinent is emigration. This means the act of leaving. Obiously the population effect would be negative. This parameter is important only when discussing certain areas smaller than the biosphere, since there is no easy why to leave the earth. Many things influence emgiration population, food and/or living space, climate changes, (hotter-colder, wetter-dryer), and geological changes (volcanoes, floods, earthquakes). Any movement is generally undertaken at great risk since the move entails changing one's accustomed habitat and, in some cases, niche. These terms will be discussed in more detail later.

Another determinent of population is immigration--coming in. This is a positive pressure and results from one of the factors listed above. It is obvious tht to have an immgre there must have been an emigrator. In addition to the reasons for leaving a particular place, there may be strong pressure to come--increased food, better weather, fewer predators.

To view these four pressures in table form and to see their effects on population, see table C-1.

Parameter	Effect
Natality	+
Mortality	-
Immigration	+
Emigration	-

Table C-1, Population Determinents

Population density is another factor to consider when discussing populations. The definition is, "number of crganisms per given area." There is a formula for determining density:

$$d = \frac{\text{number}}{\text{area}}$$

This is expressed as 432 people/square kilometer or 32 ducks/square mile. Density is a highly important factor in determining an areas carrying capacity. Carrying capacity is the number of organisms that can be supported per given area. This number varies from animal to animal and from locale to locale. Density is an important factor when an area is under study. (In laboratory exercise #1 at the end of this chapter you will be asked to determine densities of some trees in a woodlot.)

An adjunct to density determinations is change in density. This is important so that a researcher has some idea how an area is prorgressing. The formula.

$d_2 - d_1 = {}^{\Delta}D$

where d_1 = original density
d_2 = present density
${}^{\Delta}D$ = change in desnity
(usually a percentage per time)

An example: In one acre last year there were 10 deermice. This year the population was 20 deermice. Substituting in the formula:

$$20 - 10 = {}^{\Delta}D$$

$$10 \text{ miceper acre} = {}^{\Delta}D$$

in percentage: $\frac{{}^{\Delta}D}{d_1} \times 100\% = \%{}^{\Delta}D$

$$100\% \times \frac{10}{10} = 100\% \text{ increase}$$

likewise if the original population were 80 and in a year it dropped to 40, the formula would be:

$$d_2 - d_1 = \Delta D$$

$$40 - 80 = \Delta D$$

$$-40 = \Delta D$$

in percentage: $\frac{\Delta D}{d_1} \times 100\% = \%\Delta D$

$$\frac{-40}{80} \times 100\% = \%\Delta D$$

$$\frac{-1}{2} \times 100\% = 50\% \text{ decrease}$$

The change in density is such an important parameter that it bears close study in any population inquiry; it is an indicator of the rate of increase or decrease.

Population changes can also be shown through the use of growth curves and life curves. probably the most important and best known curve is that of bacterial growth. it is well established through experimental data. The curve is like the one shown in figure C-2.

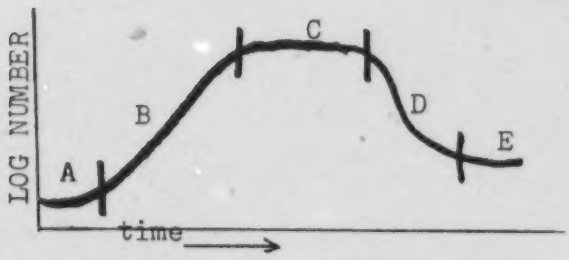


Figure C-2, Bacterial Growth Curve

It is usually divided into five parts as follows:

Letters refer to figure C-2.

A - lag phase where organism is acclimatizing to habitat

B - log phase where organisms are reproducing geometrically (i.e., 2-4-8-16-32-64-128 etc.) Birth rate > death rate.

C - stationary or static phase where population growth is not moving. here die off begins and birth rate - death rate.

D - decline phase - generally a logrithmic function and death rate > birth rate.

E - resistant phase - a small number will continue to reproduce indefinitely.

Each phase is important and there are excellent causes for the organism to behave according to the graph's prediction. The decline phase is caused when wastes and toxic build-up and organisms are being poisoned. it should be pointed out that figure C-2 is accurate only when a closed environmental system is being considered.

When populations are studied it is not enough that we graph a growth curve. Life curves for various species are also important. These are in

effect like the acturial tables mentioned earlier. They show the percentage or organisms living at a particular time. These are valuable in discussing populations and the changes they undergro. For an example see figure C-3.

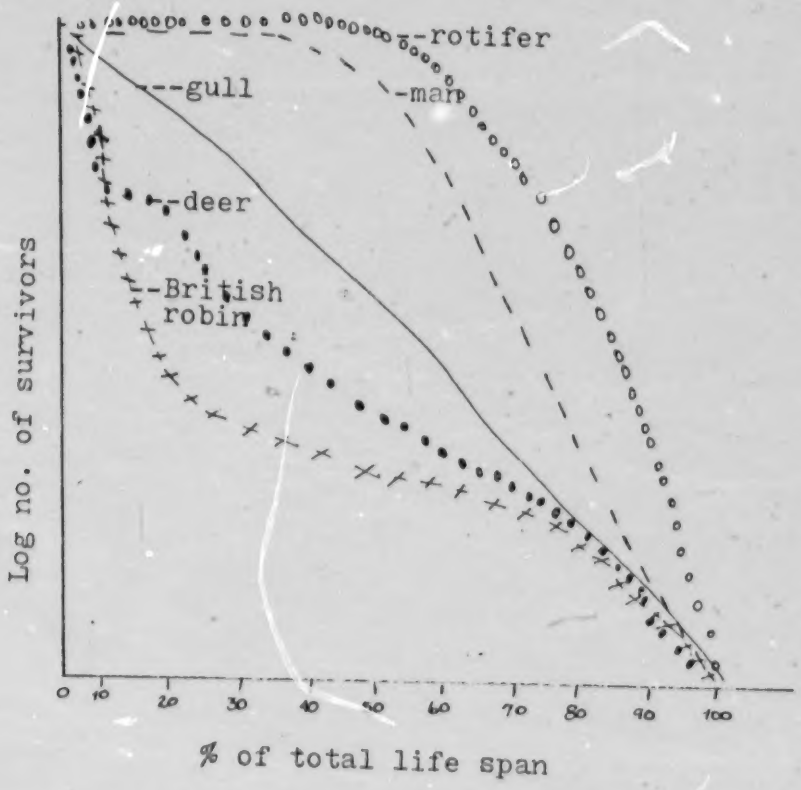


Figure C-3, Life Curve Chart

Another important parameter is describing populations is the age structure. Populations can be divided into 3 distinct groups--pre-reproductive, reproductive, and post-reproductive. These groupings were proposed by Bodenheimer and are an excellent way to visualize the status of a particular population. Taking this idea, there are three possibilities

for population: expanding, stable, shrinking. These are shown graphically in figure C-4.

Generally speaking, populations seek an equilibrium. This balance is dynamic meaning that there is flux around points but basically it remains the same. Fluctuations are generally seasonal. For an example of an off-phase fluctuation see figure C-5.

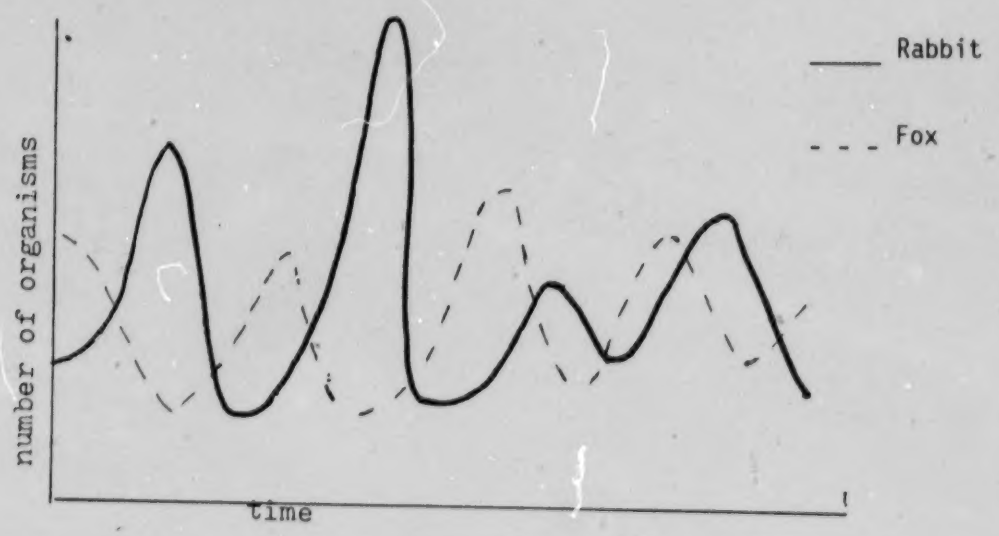


Figure C-5, Equilibrium Flux

Populations are not distributed equally throughout the world. Their life patterns may vary from area to area. The study of these fluctuations is called <u>biogeography</u>. An important term in biogeography is <u>range</u>. Range has to do with the geographical limits of the population. For example, the Venus-fly trap is found only in North and South Carolina. This is its range.

Another term is <u>ecological range</u> which refers to the particular type of environment normally inhabited by the organism. The most common place to find pitcher plant is in bogs in the northern midwest and the deep South.

Geological Range refers to the occurrence and abundance of the organism in past ages.

Biogeography also concerns itself with methods of distribution such as wind, water, land birdges, and biologic transports. Each of these things plays a tremendous role in distribution and density of organisms.

Regulation of population basically falls into two distinct groups. One is density-dependent and the other is density-independent. Density-dependent influences are basically intraspecific. The competition for food is a limiting factor of many organisms and either directly or indirectly plays a controlling role among organisms. Behavior is another density-dependent factor. The social activities of organisms change through interrelationships among organisms. Terms such as social hierarchy, peck order, territorality all express this idea of social related behavior. Genetic quality is another factor influencing competition. Basically Darwin's idea of survival is working at this juncture.

Density-independent factors cannot regulate population growth because factors controlling population are directly related to homeostatic feed-back. Weather is one factor which can regulate populations. This is rather obvious if one considers the effect a cold winter has on the insect populations. Likewise rainfall can cause population changes due either to too much or too little. Obivously these density-independent factors are related to the density-dependent ones through the effect of climate and weather on food.

Both dependent and independent factors account for migration. Migration is a two-way movement: Both going and coming. Migratory movements are generally seasonal or periodic. These moves may or may not follow traditional pathways. What triggers migration in all animals is

poorly understood. Birds have been perhaps best studied and it appears that a cold weather stimulus (generally decreasing dayligh) sends the flocks southward and likewise, a long day sends them norhtward again.

Populations interact with each other in several different ways. All these interactions can be described as symbiosis. This means living together. The various types of symbiotic relationships to be discussed will include: parasitism; mutualism; commensalism; amensalism; predation; cannibalism; mimicry; camoflauge; protective coloration.

Perhaps the best known of all the symbiotic relationships is paratism. This is a relationship where one organism benefits and another is harmed. It is the relationship that accounts for disease. If one were to be a parasite it is obvious that the victim (host) should continue to provide food and/or shelter for long periods of time, for if the host dies so does the parasite. The happy medium then is for a non-debilitating type of infection. Any parasite which causes early death is a poor parasite. Because of the tenuiousness of the parasitic existence it is necessary that large numbers of off-spring be produced since the chances of finding a new host in time after leaving the firts host are slim. A portrait of a good parasite is one which doesn't kill and one which produces lots and lots of progeny.

Another kind of relationship is mutualism. This type benefits all organisms involved in the relationship. Each of the partners is providing some service that would be difficult if not impossible for either alone. Examples are the termite-unable to digest all the cellulose that it eats through--and the Trichonympha, a small micro-organism in the termite's intestine which digests the cellulose that releases the digested products into the intestine to nourish the termite. Another example is the buffalo

tick bird who uses a wild water buffalo as a feeding ground-eating the ticks from the animal's hide. One benefits from a convenient and fairly safe food source and the other from having the ticks removed.

Commensalism is a third relationship. In this type one organism benefits but the other is neither helped or harmed. The reasons for the evolution of this relationship remain unclear. Some experts suggest it originated as a mutualistic relationship and one partner has changed slightly. An example is the shark and the remora or the pilot fish. The remora lcings to the shark and takes the leftover food bits from the feeding process. The shark receives no apparent benefit from this association.

Amensalism is a relationship where one population benefits and another population is inhibited through the activities of the first. This differs from parasitism in that nourishment is not obtained ffrom the second population. Probably the best known example is through the production of antibiotics by certain molds. Another is through changes involved in pioneer plants in succession. This will be discussed in detail later but briefly, the shade produced by oaks and hickories prevent the growth of pines on the forest floor. Asters produce a substance harmful to other asters. They can be grown only one year in a place without this self-amensalism.

Another relationship is predation. In this one organisms will attack others for food. This is closely related to parasitism as the experts who debate this topic will agree. The main difference is that predation in its extreme involves a "fair fight" concept where the victim is aware of what's happening and can endeavor to escape. The area between this and paratism ia many shades of gray.

A theory of predation has been advanced by several scientists. A graphic representation can be seen in chart C-5. This is a fox and rabbit-a predator-relationship. This will happen in an open system. In a closed system one or the other dies out. Experiments carried on with Paramecium and Didinium, it's prey, show this to be true. If both are placed into a closed container the Paramecium time and time again will devour the Didinium. When a cover of silt was placed on the bottom to hide the prey, the predator ate what was in the water and when they were gone, died. The hidden Didinium then came up and multiplied and populated the container.

Cannibalism is a very specific type of "competitive interference" or predation. This is a widely accepted method of population control among fish, rodents, birds, and primitive human societies. Most people find the idea distasteful but is a highly effective intraspecific control.

Some ohter relationships are mimicry where one animal or plant simulates another. The best known is probably the Viceroy and Monarch butterflies. Another method is to resemble some inanimate part of the environment-like the praying mantis or the walking stick. Protective coloration is a third relationship-this occurs where colors blend into background scenes--the faron's mottled coat, the grouse's color, grasshoppers, and the list is very long. All of these are highly effective and protective relationships.

There are other relationships that effect populations. One of the most important of these is population genetics. it will be recalled that genetics is the study of inherited traits. Things like eye color, hair color, height, size are genetic factors. Geneticists use a letter to represent a gene, the unit of hreredity. Since there are two genes for every trait, then two letters describe the organisms genotype (type of

genes). The terms homozygous and heterozygous-dominant and recessive, further describe genotypes. Inheritance of factors is a change process based on the laws of probability.

Population genetics concerns itself with the description and identification of genes in populations. The total sum of genes that any one organism has is said to be that organism's genome. It is obvious that within populations the genome is not the same for each individual. The population then has a larger set of genes upon which to draw than does any one individual. The total of all the genes within a population is called the gene pool.

Two Europeans (Hardy-Weihberg) who studies gene pools came up with a startling revelation. They said "that gene frequencies in a freely interbreeding population remain constant barring selection or mutation." What this means is that nonadaptive recessive traits will not be lost because of a dominant allele (allele is simply a gene's alternative form). This says that there are factors at work which maintain the same relative gene numbers in a group. Let's consider an example of blood groups M and N. These are factors which have no selective value. With these two genes there are three possibilities for genotypes: MM, MN, NN. The formula for figuring out the percentage of the offspring or the frequency of alleles is: p^2: 2pq : q^2, which is simply $(p + q)^2$ where p = one allele and q = the other. Obviously $p + q = 1$ and squaring $(p+q)2=(1)^2$ or $(p+q)^2 = 1$ or $p^2 + 2pg + q^2 = 1$. For a problem, let p=M allele and q=N allele. We can check blood types and arrive at an answer of phenotype M or N or MN. Let us assume we do check and find M=29%, N=21%, MN=50%. Gene frequency, then can be determined by the formula:

$$p = \frac{M + \frac{1}{2}MN}{100}$$

substituting

$$p = \frac{29 + \frac{1}{2}(50)}{100}$$

$$= \frac{29 + 25}{100}$$

$$= .54$$

Remember that p was frequency for M allele and since p+q=1, or

$$q = 1-.54$$
$$= .46$$

So this formula says M has 54% and N has 46% of the total alleles in the MN system. We can substitute these values in our formula and see that:

$$p^2 + 2pq + q^2 = \text{total}$$

$$(.54)^2 + 2(.54)(.46) + (.46)^2 = \text{total}$$

$$.2916 + .4968 + .2116 = \text{total expected}$$

MM MN NN

Refering to the earlier data, it is noted that MM = 29, MN = 50, NN=21. So this data indicates that random mating occurred in the previous generation.

This is fine as long as all three possibilities can be seen. What about a recessive gene like albinism. For convenience: A=normal pigment, a=albino

Therefore: AA = normal
Aa = carrier normal
aa = albino

When populations are observed, the albinos (aa) can be counted, but what of the other genes, a hidden in Aa types. The formula described

earlier helps scientists discover these hidden genes. In human population approximately 1 out of 20,000 are albinos.

$$\text{So: } q^2 (aa) = \sqrt{\frac{-1}{20,000}}$$

$$q = \sqrt{\frac{1}{20,000}}$$

$$q = \frac{1}{141}$$

this means $p = \frac{140}{141}$ because $p + q = 1$

$$p = 1-q$$

$$= 1 - \frac{-1}{141}$$

$$= \frac{140}{141}$$

Substituting: $(p = q)^2 = 1$

$$p^2 + 2pq + q^2=1$$

$$\left(\frac{140}{141}\right)^2 = {}^2\left(\frac{140}{141}\right)\left(\frac{1}{141}\right)+\left(\frac{1}{141}\right)^2$$

$$\frac{49}{50} + \frac{1}{70} + \frac{1}{20,000} = 1$$

AA + Aa + aa

$$\underline{1}$$

These data show that nearly 1.5% (70 x 1.4) of all "normally" pigmented people carry the gene for albinism. In relative terms, the chance combination of Aa and Aa is very small, enough so that only 1 out of 20,000 get these two genes!

To reiterate--the genes in popultions maintain themselves unless there is something selecting against them. This is the principal of Hardy-Weinberg.

It should be kept in mind that Hardy-Weinberg principle applies only with large populations. In small populations genes may be lost from the gene pool and until reintroduced by immigration or mutation remains lost. It is because of the genetic drfits that variations can begin to develop within populations. The study of local variations is the footstone of biogeography.

Any study of biogeography recognizes that the variation in terminology is as diverse as the person listing them. For the purposes of this study, they will be divided into six biogeographical regions, each of these more or less encompasses a continental area. They are named Paleartic, Neartic, Neotropical, Ethiopian, oriental, and Australian. These are shown in Figure C-6.

Figure C-6 - Biogeographical Zones.

Since world-wide study is impractical in this space, only the North American area-neartic-will be considered. In a listing of common organisms: flora-sugar maple, dogwood, Labrador tea, sunflower, maize, gourds, tobacco,

sagebrush, reindeer moss, pumpkin; fauna-mountain goat, muskrat, caribou, pronghorn antelope, bison. As can be seen from even a customary inspection this list is very borad but it is not as broad as the Paleartic. By no means should this list be considered all inclusive. It does represent some typical endemic (natural) species.

It is expected that there be wide diversity within the region (Neartic) since it encompasses such a broad area. The changes are changes in degree rather than substance. Each change is very gradual and to an observer traveling very slowly from coast to coast or North to South, the changes would be imperceptible just as a baby changes without its parents being aware of the changes. More will be said about this later in the chapter.

Studies of biogeographical regions give rise to study of the communities which make them up. Communities are composed of many populations which interact in many ways. Communities behave like individual populations to a degree but in large measure there are certain traits peculiar to the community.

Dominance was mentioned in relationship to populations but in a discussion of community it assumes new meaning. Whereas in population studies it meant only that one organism was the strongest, biggest, etc. in community studies we are talking about populations that assume positions of importance. In the laboratory exercise on mapping a forest the dominance of each of the tree species is computed. This determines the importance of that tree to the fabric of the forest. This same yardstick can be applied to other types of organisms-plants, animals, protists. It should be obvious that dominant species can change depending on the conditions prevailing at the time. For example, if two species X and Y are codominant at a rainfull level of 20" per year and rainfall fall drops to 10" a year, species Y

assumes total dominance. Likewise if rainfall were to increase to 30" a year, then species X would become the sole dominant. Conditions, then, affect dominance values.

When dominance is discussed it should be recognized that we are talking about organisms at the same trophic level trying to occupy basically the same niche. What then is niche? The modern definition of niche is provided by G. E. Hutchinson:

> "the functional role of an organism in the ecosystem as well as its position in space and time."

Species diversity within a particular community is a much studied entity. Because of great amounts of study, there is much confusion due to incompletely defined terms, ideas, etc. Many persons did qualitative work but in order to do any comparisons there needs to be some type of quantification. Many mathematicians and ecologists have worked on this. Probably the most used formula is the Shannon-Weiner Index:

$$H = \sum_{i=1}^{S} (pi)(\log_2 pi)$$

where H = diversity index
s = number of species
i = ranking in ascending order of abundance
pi = portion of individuals of the total sample belonging to the ith species.

Some biologists have questioned whether this has biological significance. The question has not yet been satisfactorily answered. It is true that this index places significance on abundance--it is also known that abundance does not in and of itself have overwhelming significance--they many or may not be most important.

Despite the disagreement on how to measure the diversity gradient there is general agreement that one exists. Several of the prevailing theories are discussed briefly in figure C-7.

1. Time theory-purposes diversity relates to evolutionary time. Thus older communities are more diverse. Torpical communities, being warmer, mature faster and are more diverse than more northerly communities.

2. Spatial heterogeneity--the more complex and heterogenous the community, the greater the diversity.

3. Climatic stability--the more stable the climate ghe greater the diversity.

4. Competition--in severe areas like artic tundra, the selection is by physical stress--since stress is small then diversity is less.

5. Predation--since diverse communities support many predators they have effectively regulated the diversity through their control.

Figure C-7 - Diversity Gradient Theories

All communities have a physical part and a biological part. In most parts these are integrated into a whole. The forest community has some structure-hysically it is divided into canopy, understory, shrub, and herbaceous areas. The canopy is those dominant trees which grow the highest. Under this layer is found the understory-trees which do not grow as high as the canopy trees. Beneath these layers there is the shrub layer of very short trees and shrubs. Finally on the floor there is the herbaceous layer.

The biological interaction can be shown in the gradient as to necessary sunlight for survival. See figure C-8.

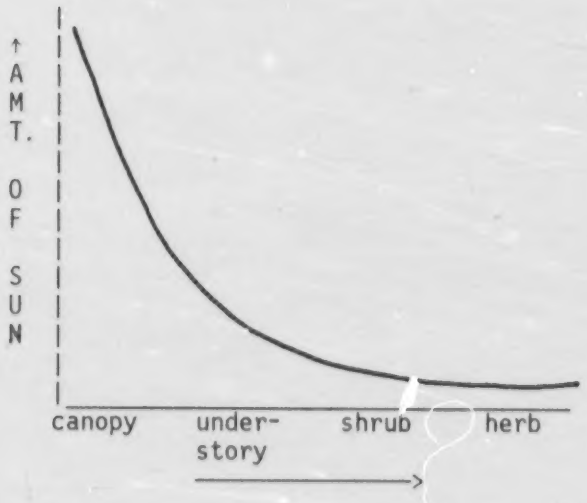


Figure C-8 - Sunlight required by various plants of a forest community.

These ideas of layering in forests hold true in other communities especially acquatic ones. Grass lands and deserts have strata even though they ar enot as well defined as fores or aquatic systems.

Since there are obvious differences in communities, how is it possible to compare them? Many scientists have tried to devise workable methods. probably the most widely accepted is that of Raunkaier. This method allows rapid comparison by looking at these components. It is obvious that this classifiction system works only in terrestrial communities. See figure C-9.

Where two or more communities meet there are characterisitcs of each community. These areas are enough different to be designated an ectonal area. The zone may be very narrow like between a field and a forest or very wide like between the Eastern dicidious forest and the grasslands. Because there is this wide diversity in these ectonal areas, this phenomenon has been called the edge effect.

Name	Description
Therophytes	Annuals survive unfavorable periods as seeds. Complete life cycle from seed to seed in one season.
Geophytes (Cryptophytes)	Buds buried in the ground on a bulb or rhizome.
Hemicryptophytes	Perennial shoots or buds close to the surface of the ground; often they are covered with litter.
Chamaephytes	Perennial shoots or buds on the surface of the ground to about 25 cm above the surface.
Phanerophytes	Perennial buds carried well up in air, over 25 cm. Trees, shrubs, and vines.
Epiphytes	Plants growing on other plants, roots up in the air.

Figure C-9 - Raunkaier's Life Forms

Since aquatic systems are also deserving of study some limnologists have devised a system for aquatic classification. Perhaps the foremost was done by Dansereau. Figure C-10 shows this scheme.

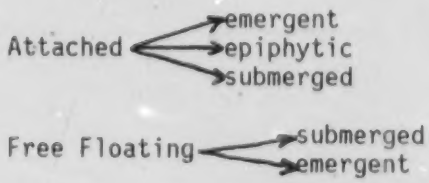


Figure C-10 - Aquatic Life Forms (after Dansereau)

As we were talking about these ecotonal areas the gradual change from one community to another was discussed. These changes are not abrupt; they fall along what is called a continuum.

Another type of continuum is illustrated through succession. Succession is defined as the gradual change in species composition over time

give rise to an ultimate or climax community. The reate of time required for formation of a climax community varies according to place and the organisms involved. For example, consider succession in Piedmont, N.C. If we were to scrape the soil away and leave the base bedrock exposed, the following series of events would take place:

Event	Approximate Time
soil formation	1" per 1000 yrs. (need 6")
broomsage stage	3 years
asters	1-2 years
cedars	10-15 years
pines	15-100 years
oaks, hickories	100-???

Each event allows others to occur or causes others to occur. After astrs have been grown in the same area for a period of several years they poison the soil for other asters. Cedars are then able to begin growth and the slightly less resistant pine seedlings are now protected. Finally the pines protect the hardwood seedlings and they grow to maturity and in turn protect other hardwood seedlings which grow, mature, more seedlings on and on---Climax.

At this point it should be stated that not only do plants undergro changes the animals that are dependent on them do also. It is always easier to study plants isnce few posses the bad habit of running from you or trying to bite you, etc.

Succession takes place in aquatic communities also. Here succession is called eutrophication. Water has the habit of becoming dry land; that is the tendency of all bodies of water---to become dry land. More will be said about cause sof eutrophication in the section dealing with limnology.

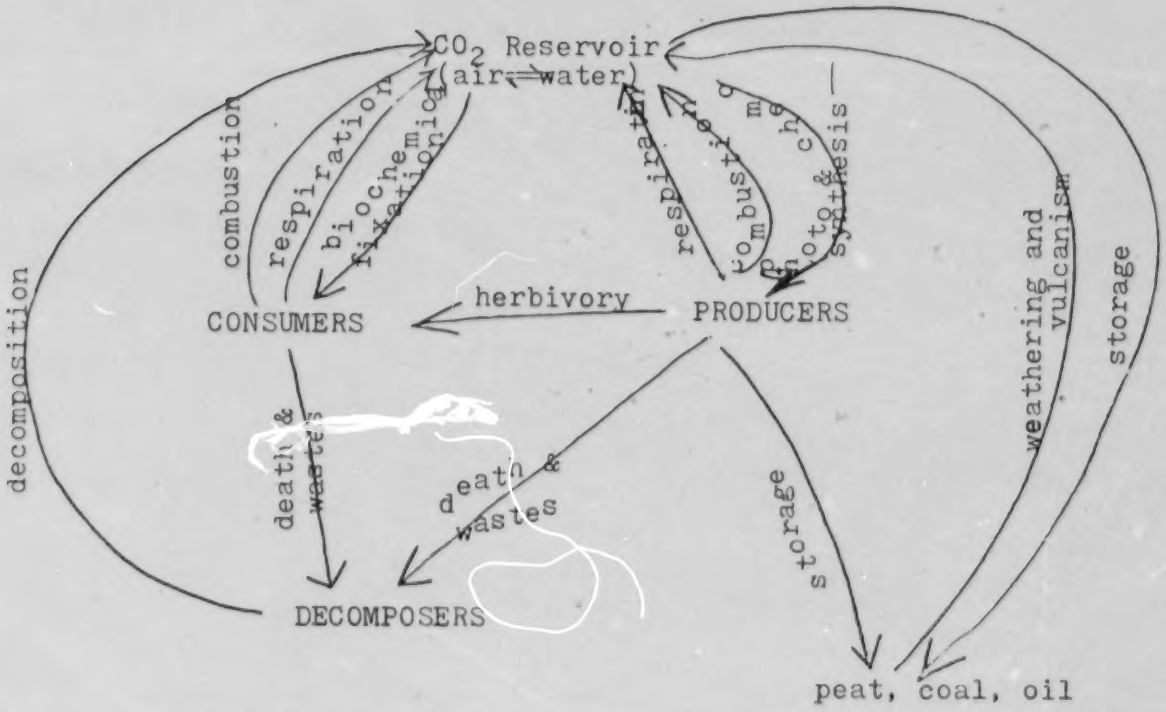
It should be emphasized again that succession is described only through the term continuum. It is like a smear or slur---no point is really that

specific in the continuum you are aware that you have arrived but not that you are arriving.

Succession is sometimes discussed in terms of the development of the ecosystem is ecosystems are groups of interacting communities and their surroundings. One of the major aspects in the study of ecosystems is biogeochemical cycles. These cycles represent nutrient flow in a system and are necessary for its survival.

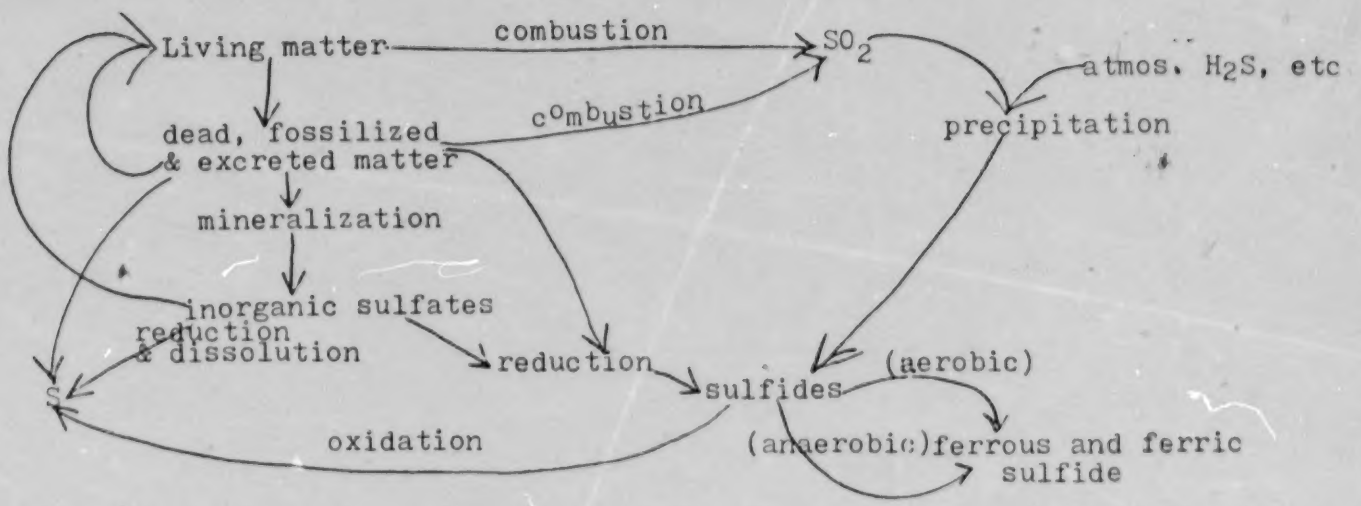
Biogeochemical systems fall into two main types--gaseous and sedimentary. The gaseous cycles include carbon, nitrogen, and part of the water cycle. The major sedimentary cycles are phosphorus, sulfur, and iodine.

One example from each type will be illustrated. These illustrations are generally indicative of the others even through there will be minor



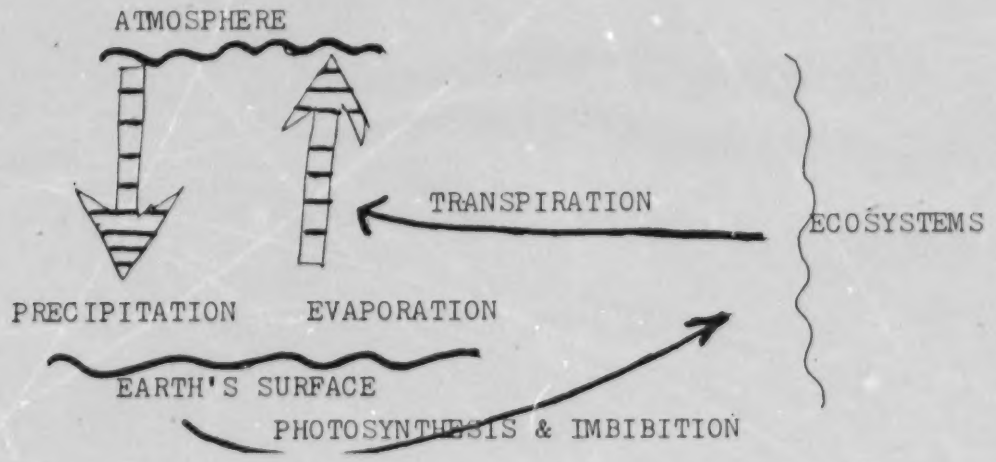
C-11--Carbon Cycle

variations. See the figure C-11 for the carbon cycle and C-12 for the sulphur cycle.



C-12--Sulfur Cycle

There is one cycle that holds tremendous significance for all living things and that is the hydrologic cycle. The general pattern of the hydrologic cycle is illustrated in C-13.



C-13--Pattern of Hydrologic Cycle

Water is a strange molecule. it behaves contrary to expected chemical patterns. Most compounds as they get colder become denser. For eater this

is true only to 4°C.; after this temperature water becomes less dense--this

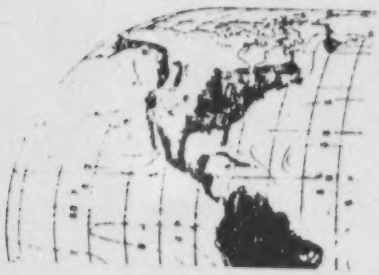
C-14 Soil Associations in North America
This diagram taken from Ecology and Field Biology 2nd Ed. 1974.

is why ice floats. Another feature of water is that it can absorb and hold large quantities of heat with only slight temperature fluctuation. Each of

these interesting facts about water will be discussed in more detail in the Limnology chapter.

In addition to the biogeochemical cycles another important aspect of the ecosystem is soil. Soil is the site of growth for most plants and through food production the site of sustenance for animals. Soil is formed from the weathering of rocks, decay of organisms, and in general represents the place where biotic and abiotic aspects of the environment meet. Soils come in several varieties based on mineral content, color, drainage, and

C-15--Rainfall mean (amounts)



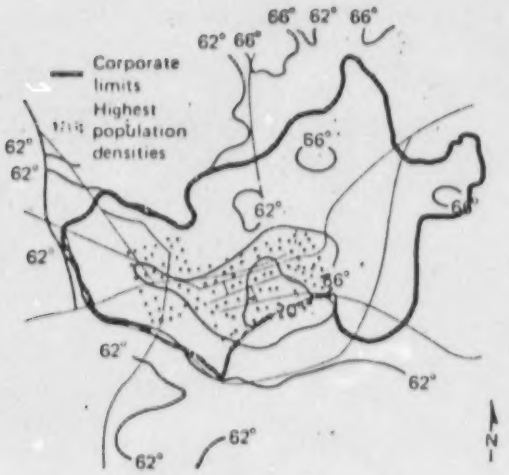
C-16--Temperature (means)

texture. Each type of soil has particular plant associations and therefore animal associations connected with it. Figure C-14 shows soil assocations in North America.

It is noteworthy to mention that the study of soila and soil and soil types has a separate science. Since this is only an introductory study no more time will be spent on soils--the interested student is directed to numerous publications in physical geography which deal at length with this topic.

Climate can play as significant a role in ecosystem development as soil. Climate is subject to fluctuations and generally when climate is discussed the term mean is used. Two climatic factors generally considered are rainfall and temperature. These can be seen in figures C-15 and C-16. As stated earlier only the neatric zone is shown.

When these charts are studied it is important to remember that small varitions significant to a particular area are not shown. These microclimates can be extremely important but because of their small affective domain they are omitted. While the microclimates cannot be shown it is important to know possible sources of variation. One source is the north and south slopes of hills. The south slope receives much more solar energy (in neartic zone) and is therefore warmer. Entire sections of mountainous or hilly terrain can be affected. Likewise in valleys the climate will tend to be different than on mountain tops or flat land without the mountains at the same elevation. A final microclimatic is seen over the cities. They have a unique weather situation. Checking forecasts of a city they generally give temperature and precipitation data for the city and suburbs they occasionally vary tremendously. This effect can be seen even in small cities. See figure C-17.



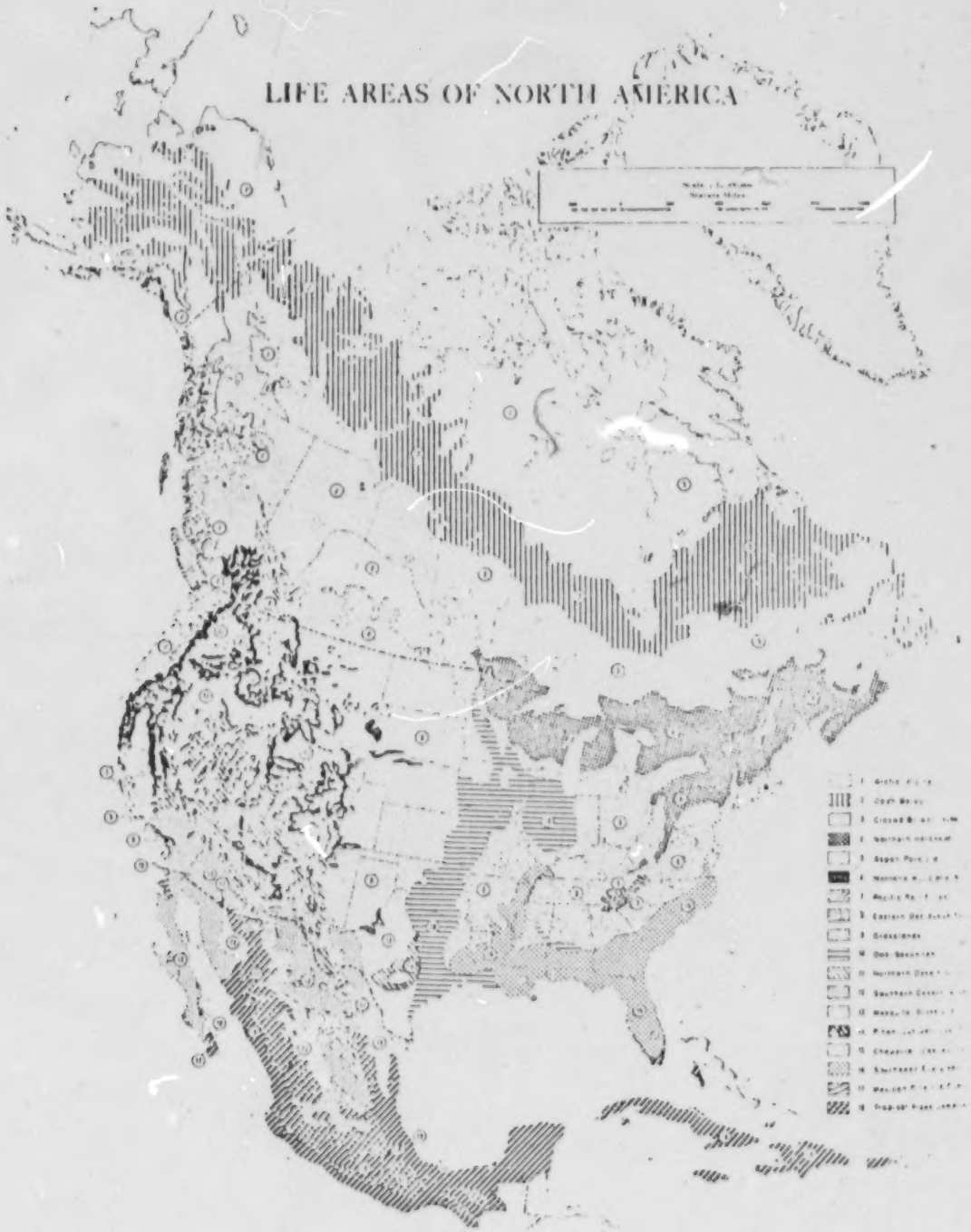
C-17--Thermal pattern of night air in Chapel Hill
(From Kopec, 1970)

The classification of ecosystems is a process about which there is much disagreement. Everyone agrees to a classification system but no two are exactly the same. The differences come from the fact that definitions used by the various classifiers differ. The system used here is from the U.S. Fish and Wildlife Service and is shown in figure C-18. These classifications are also arbitrary and in no way should this be interpreted as the only way or even the best way to show the life areas or biomes of North America. This way was chosen because of the author's personal bias.

Since earlier it was stateo that the two most imporant climatalogical factors were precipitation and temperature it would be only logical to assume that these factors have some effect on the biomes. Their cumulative effect is shown in C-19.

Climate's effect is great but so is the effect of man. probably no other creature has caused such great ecological change in such a short time. The ultimate implications of our changes may not be felt for years to come.

C-18--Biomes of North America
(map by J. Aldrich of U.S. Fish and Wildlife Services)



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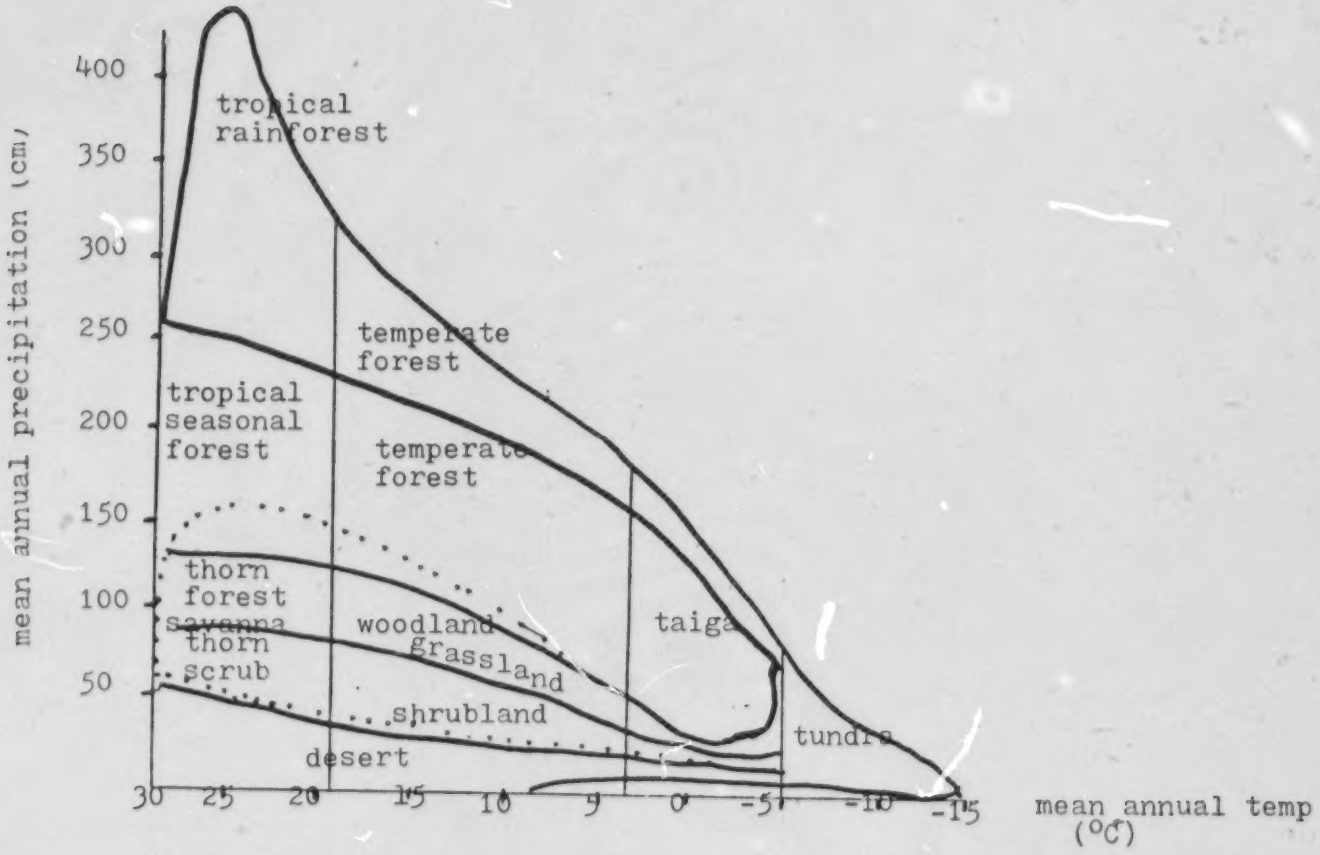

C-19--Relationship of Biomes to Climate

What is it that keeps the ecosystem going? Most authorities agree that there is some type of mechanism which "tells" the organisms when it is time to flower, drop their leaves, reproduce, hibernate, migrate. The fact that these things happen over and over again indicates such a timing mechanism. These periodic events are described variously as periodicity and biological clocks. Their workings are not understood at the present. Research in these areas is ongoing but an answer awaits the researcher who asks the correct questions.

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Management of these rhythms is now and has been economically profitable. The most obvious is causing flowers to bloom in winter -- florists think this very import. Work is going on in management as it is in periodicity. The two are inextricably linked.

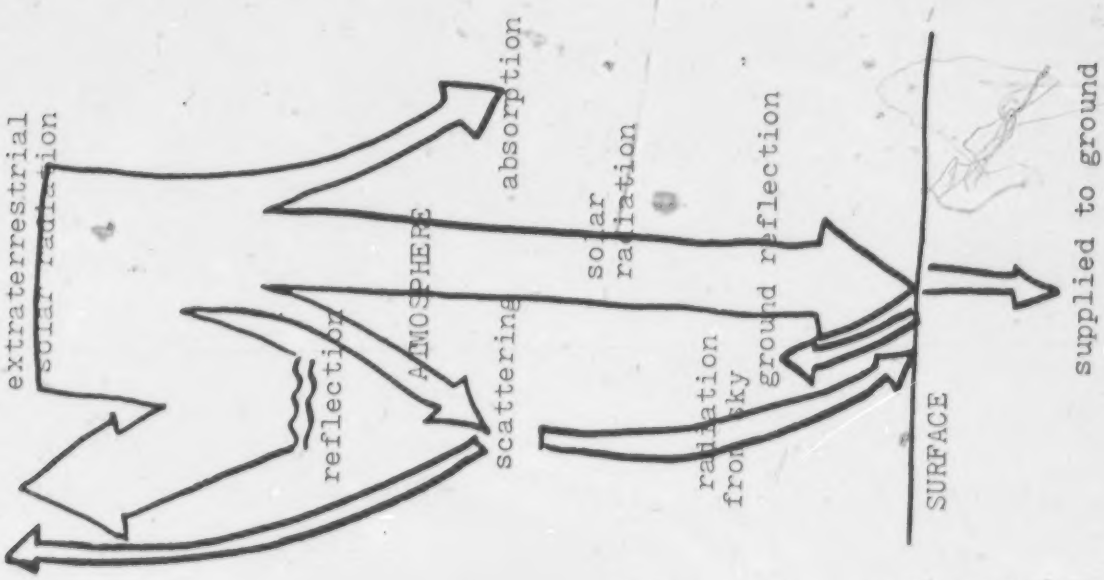
Managing ecosystem need not be solely periodic--other areas like production of trees, game animals, etc. lend themselves to the same type manipulation that is common in human life. Perhaps we are being managed?

One important work which should be mentioned here is E. P. Odum's "Strategy of Ecosystem Development," Science, Vol. 164, 18 April 1969, pp. 262-269. While not the easiest reading, it is chock full of thought-provoking ideas.

This reading provides a fitting conclusion to the section of Chapter III which deals with the qualitative aspects of ecology. The last part of the chapter will deal with the quantitative aspects.

Probably the one word which best describes the task of the last section is bioenergetics-the energy of life. The fundamentals for this idea were laid down in the laws of Thermodynamics. The first law states that energy is neither created nor destroyed although the form may change. The second law says that in passing energy from one place to another part of the energy is changed to a form that cannot be passed on any further. The first law leads to a condition called entropy. This has aptly been called disordered energy. Applying the second law--every energy transfer has some entropic loss. This loss in a closed system continues to accumulate until the amount of free (i.e., non-entropic energy) is at a minimum and entropy is at a maximum. The closed system would tend to run down-to stop; the open system, with continual energy input, remains seemingly unaffected. The system on the earth is open-the sun is constantly supplying us with energy. This

energy reaches us in the form of light and is converted to other forms-chemical the most important. Does all the energy that gets to the earth get utilized? The answer is obvious. See figure C-20.



C-20--Energy input at the surface

That energy that eventually reaches the surface is utilized by plants in the process called photosynthesis. The simple formula for this is:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sun}} C6H_{12}O_6 + 6O_2$$

The sunlight activates the cholorophyll to allow for electron movement. This electron movement causes energy changes and these surplus energies are trapped in the sugar molecule--stored, waiting for some animal to utilize it. Some of this stored energy never gets utilized what happens to it? Perhaps the best explanation of this can be seen in figure C-21. This figure is an energy flow diagram representing the various pathways of energy movement. Study it carefully.

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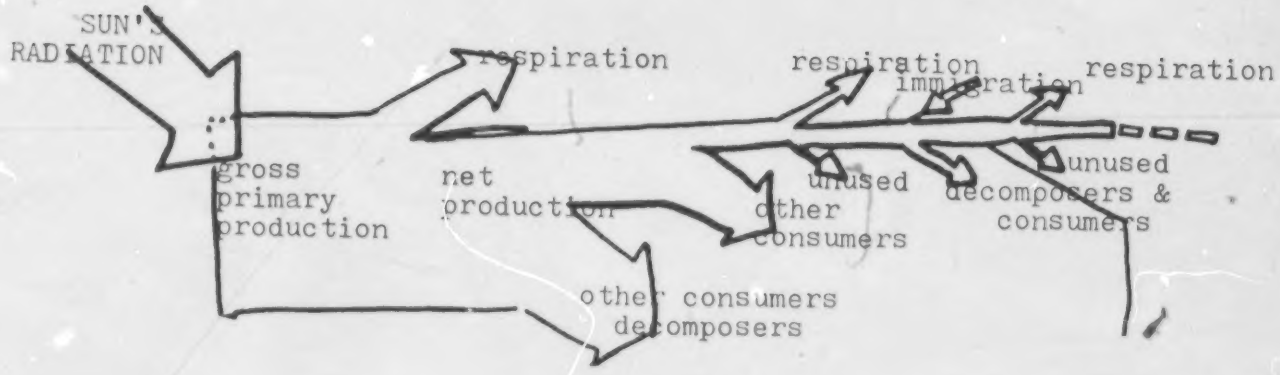


C-21--Energy Flow (generalized)

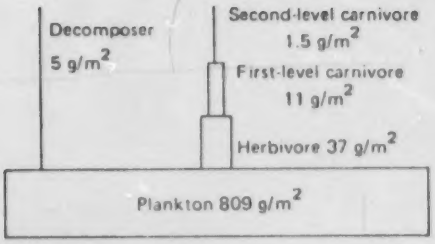
The idea of energy flow must be tied in with the idea of food chain (food web) which is simply a linear explanation of who eats what. The diagram in figure C-22 shows this plainly.

plankton <——— fish <——— big fish <——— man

C-22--Food Chain

Along with the idea of food chain comes the idea of food pyramid sometimes called the Eltonian pyramid or trophic level diagram. Trophic level deals with autotroph, heterotroph, herbivore-carnivore. This is seen in figure C-23.

It is certainly obvious at this point that ecology is not a short topic-it has not really been adequately covered. The amount of new knowledge in the ecological field makes it hard to keep up. Much work is, at present, being carried out. The purpose of this chapter is not to make you an expert but rather to introduce you to some concepts that are basic to all ecological studies. Almost all libraries now carry books on



(b) Pyramids of biomass

C-23--Food Pyramid

ecological topics as well as most bookstores. Read and learn more about this facinating but complex topic.

UNIT IV - LIMNOLOGY

"Water, Water everywhere, nor any drop to drink."

- Coleridge

Of all the precious substances that we have on earth, water must rank near the top of a list of the most precious. Without an adequate and clean supply of fresh water, life as we know it must cease to exist. This chapter will deal with water studies and water problems. There are six areas that will be covered. 1) historical; 2) biological productivity; 3) geology of lake morphometry; 4) water chemistry; 5) biotic communities; 6) physical parameters.

Historically much of the work in limnology (Gr. limnos-water; logos-study of) was conducted in Europe. It was here that much of the background for today's science lies. Many mean who have had a hand in the development of limnology as a science are probably little known to the general public. None of these men was as important to the development of limnology as Forel. Forel has been called "the Father of Limnology." It was he who first understood thermal characteristics of lakes and to develop a terminology for usage. He also was the first to describe the physical character of lakes in detail.

American limnology revolved around one school until the fifites---the University of Wisconsin. There were tow men who through tireless devotion to limnology did a great deal to make it a legitimate science in the United States. Their names were E. A. Birge and C. Juday. Birge and Juday were responsible for much of the work that was done on the lakes in the states of Wisconsin, Indiana, Illinois, Michigan, Minnesota. Their studies

included thermocline, wind effect of a lake, plankton analyses, chemistry of dissolved solids, and insolation (heat budges). After the deaths of these two men the program at Wisconsin changed direction and ceased to be a guiding force in American limnology.

It is only natural that those areas where natural lakes abound should also be those areas where the most work is done with freshwater systems. The University of Michigan has a very good program at their biological station. Michigan State University has an excellent research center devoted to limnology located at Gull Lake near Kalamazoo and Battle Creek. Dr. George Lauff, director of the facility, Dr. Kenneth W. Cummins, Dr. M. J. Klug, Dr. Robert G. Wetzel and others are devoting themselves to find answers to the questions which are till unanswered about water.

There are multitudes of other persons and other schools that are researching and writing about limnology. Since this is not to be a history of limnology only two more persons will be mentioned; P. S. Welsh, author of Limnological Methods, set the signs for others to follow. His book has provided students with much data and procedures to follow in the study of water. The other man is G. Evelyn Hutchinson, author of the multivolume... Treatise on Limnology.

While a biographical history is interesting only through quantitive study of lakes can man hope to understand the complexities of the system. Lindeman writing in the journal Ecology (23:399-418) discusses "The Trophic Dynamic Aspects of Ecology. In general, he says predators are less specialized than their prey in food habits. This means that predators use many types of herbivores for food but herbivores are typically restricted to only one type of plant.

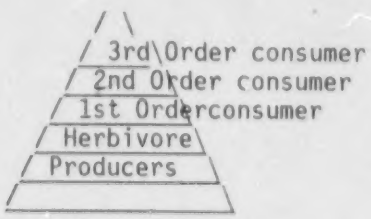
Working with this assumption Lindeman dervied the following formula to help in understanding the process:

$$\frac{<\Delta\ n}{\Delta t} = \lambda_n - \lambda_{n^1}$$

Δ = change in
Λ_{-n} = energy entering or leaving system
t = time
λ_n = contributions from previous level
λ_{n^1} = energy lost frm and the amount handed to next level Λ_{-n+1}

This is a mathematical way of stating the fact that not all the productivity at a particular trophic level is passed on to the next level. There is a formula for comparing various trophic levels given as $\frac{\lambda_n}{\lambda_{n-1}} \cdot 100$ = % passed. This can be carried all the way back to λ_o but ususally is done only in relation to the preceeding level. (Note: λ_o = incident sunlight; λ_1 + producer level; λ_2 = primary consumer; λ_n = nth trophic level.) Rarely do systems have more than five trophic levels.

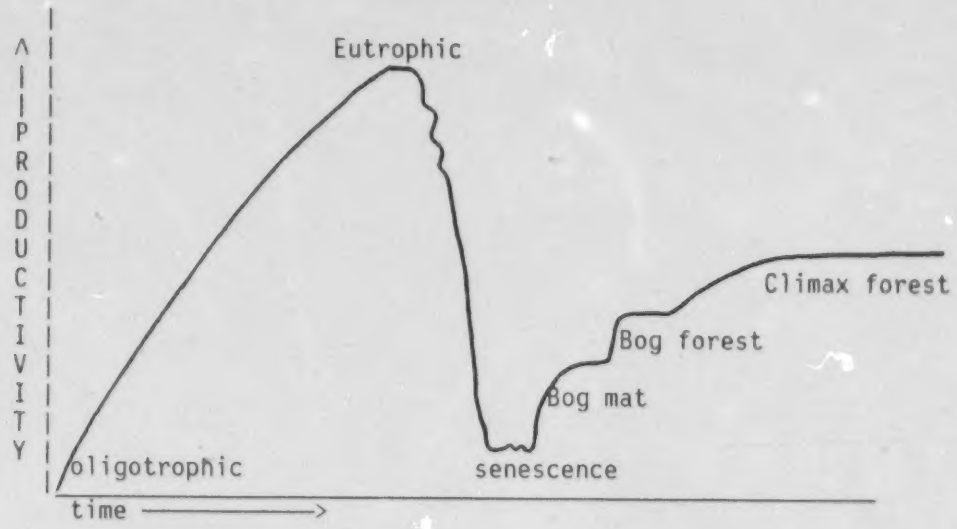
Thre reason for only five trophic levels can be found in the Eltonian pyramid of numbers or the so-called food pyramid. See Fig. D-1.



D-1: Food Pyramid

In lakes there is a gradual build up of producing organisms in the water system. This build up leads to the change of a sytem from an oligotrophic (non-producing) lake to a eutrophic (highly productive) lake. Lindeman's formula helps explain this type of build up. Using the data

generated from his formula and others the following representation has been made: (See Fig. D-2).)



D-2: Succesional Pattern

These changes, as seen in the graph, take place over long stretches of time. These changes can in many cases be related to geological and morphological changes in the basin.

Tectonic lakes are those which have been caused by movements of the earth's crust (i.e., earthquakes, folds, faults, etc.) Relict lakes are caused when part of an ocean is cut off from the main body of water. This "lift-over" water becomes a relict lake. The Graben lakes happen when a section of earth shifts downward in relation to the sides. At least two sides of a graben are faults. The Rift Valley lakes are formed along a fault line extending through Africa.

Alluvial lakes are caused by subsidence of soil along an outwash plain. Upwarping of the earth's crust in the Great Lakes left depressions destined to fill with water.

I. Tectonic
   - A. Relict----------Caspian Sea
   - B. Graben----------Lake Baikal
   - C. Rift Valley----------Lake Tanganyika
   - D. Sinking Alluvial till----------Reelfoot Lake
   - E. Upwarping-rebound----------Lake Victoria, Great Lakes Region

II. Volcanic
   - A. Extinct craters----------Crater Lake, Ore.
   - B. Lava dams----------parts of Grand Canyon

III. Glacial Activity
   - A. Cirques----------common in mountainous areas
   - B. Syncline----------Lake Superior
   - C. Kettle (Ice Block)----------Gull Lake, Mich.
   - D. Moraines----------ends of glacial advances

IV. Solution Lakes----------areas of limestone concentration

V. Fluvial
   - A. Plunge pool----------base of Niagra Falls
   - B. Oxbow Lakes----------Oxbox Lake, Oklahoma

VI. Shoreline----------sounds of North Carolina

VII. Organic
   - A. Beaver----------areas of beaver habitation
   - B. Man-made----------Lake Norman

VIII. Meteorite----------Lake Singletary

Fig. D-3: Geology of Lake Formation

Volcanic lakes are easily understood through study of the chart D-3. Glacial lakes, like Cirques, are simply circular depressions, usually in mountains, caused by glaciers flowing down the hills. Synclines are layers sloping down in opposite directions. Kettle lakes are depressions left when an ice block breaks off the main glacier and melts leaving a lake. Moraine lakes form in the dirt, bolders, etc. that are pushed in front of a glacier and left by its retreat. Solution lakes are similar to alluvial lakes except a solution subsidence is caused by underground erosion of limestone.

Fluvial lakes are river lakes caused by actions of flowing water. A plunge pool forms where a waterfall strikes the ground. An oxbow lake is formed by a meandering river. It is a bow shaped lake in an abandoned river channel. Shore line lakes are created by closing sounds or bays to the ocean. The N.C. coast is a prime example of this occurrence. In the past there were eleven inlets between the sounds and the Atlantic--now there are three!

Organic lakes need no further explanation than in figure D-3. The Meteor lakes are perhaps the most interesting to think about, being caused by meteor impact.

Studies of lake formation are by no means a complete study of morphometry. The study of the shape of the basin is also important. Many techniques exist for determining this shape. They range in degree from aerial photographs to transit determination from sonar to plumb pole. The more accurate results one desires then the more careful must be the measurements.

After having achieved an accurate morphometric map of a particular lake, one may, through use of Olson's technique arrive at some important conclusions concerning the lake--its productivity, life areas, etc. Olson's Technique is the subject of Lab. # D-1.

PHYSICAL PARAMETERS

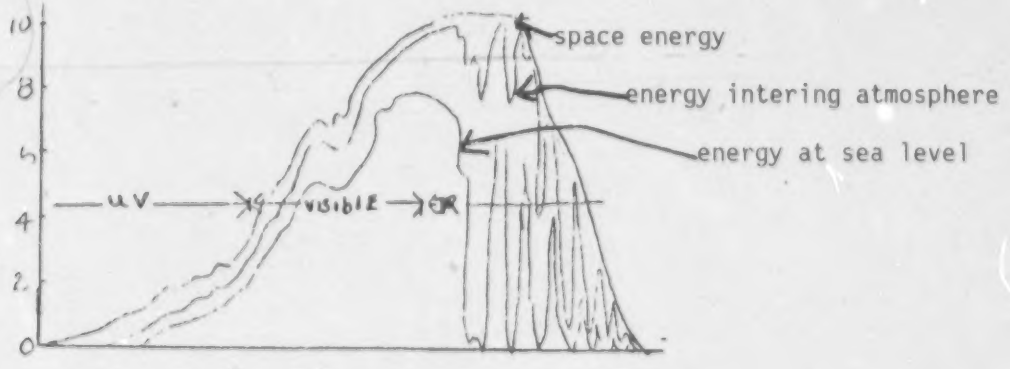
Aside from the structure of the lake itself, probably the most important aspect of limnology is the study of solar radiation. It is through the sun that the lake's energy system is fed.

Use of energy within the lake system is very inefficient as can be seen in Figure D-4. This graphically illustrates the small amount of energy eventually fixed in the bodies of the top carnivores in the system.

	Sample showing relative amts.
top carnivores - 10%	0.32 calories
Carnivores - 10%	3.2 calories
Herbivores 8%	32 calories
Photosynthesis 0.4%	400 calories
Solar Radiation 100%	100,000 calories

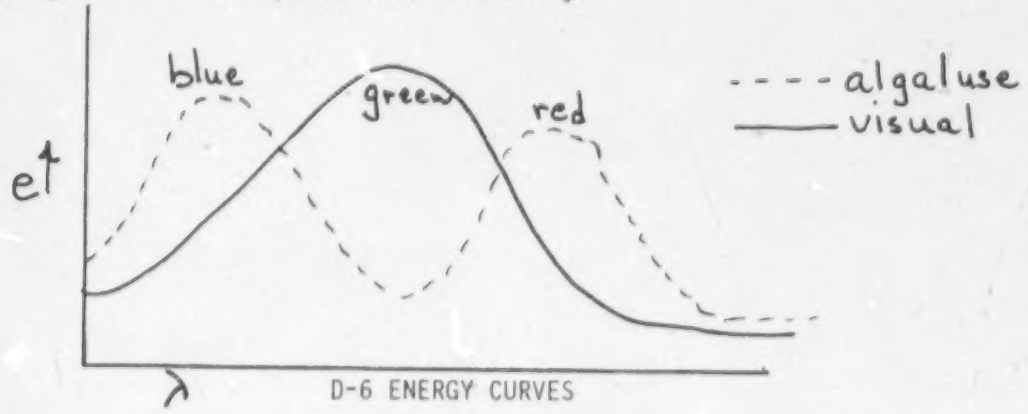
D-4: Energy Transformation within a System

Incoming light has several different components. The longer wavelengths are infrared, the medium waves are the visual spectrum, and the short ones are the ultraviolet. Of course not all light energy that comes in is utilized by living things on the Earth. The comparisons of various aspects of light can be seen in figure D-5.



D-5: Aspects of Light Energy

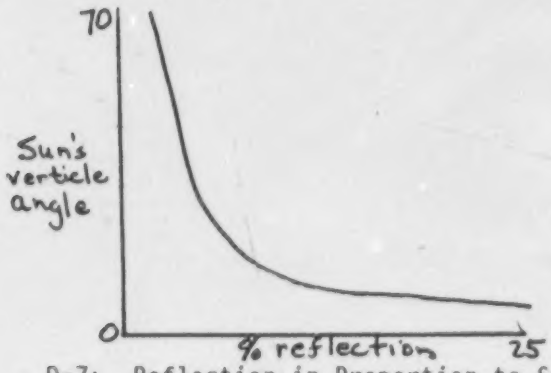
Living things are most sensitive to the visual part of the spectrum. The visual spectrum has been learned by many students using the memory device --- ROY G. BIV. This man's name stands for the colors of the spectrum in order...red, orange, yellow, green, blue, indigo, violet. It might be assumed that light has pretty much the same energy no matter what the wavelength. This is not correct. If plants were able to utilize all wavelength of light why then are most plants green? If green is the visible color very little green is being absorbed and most is being reflected. Experiments have shown that plants do best in either blue or red light. A look at figure D-6 will explain this more fully.



D-6 ENERGY CURVES

Everything that has been discussed thus far deals with light in general. Light in a water system has even more parameters to consider. Light falling on the waters surface does not necessarily reach the photosynthetic organisms within the system. First of all since water is highly reflective a great amount of light never penetrates the first centimeters. This reflecting is compounded by the angle of the sun's rays incident to the water. Figure D-7 illustrates this idea.

Once the light gets through the surface there are various things at work to absorb the light and prevent its transmission deeper into the



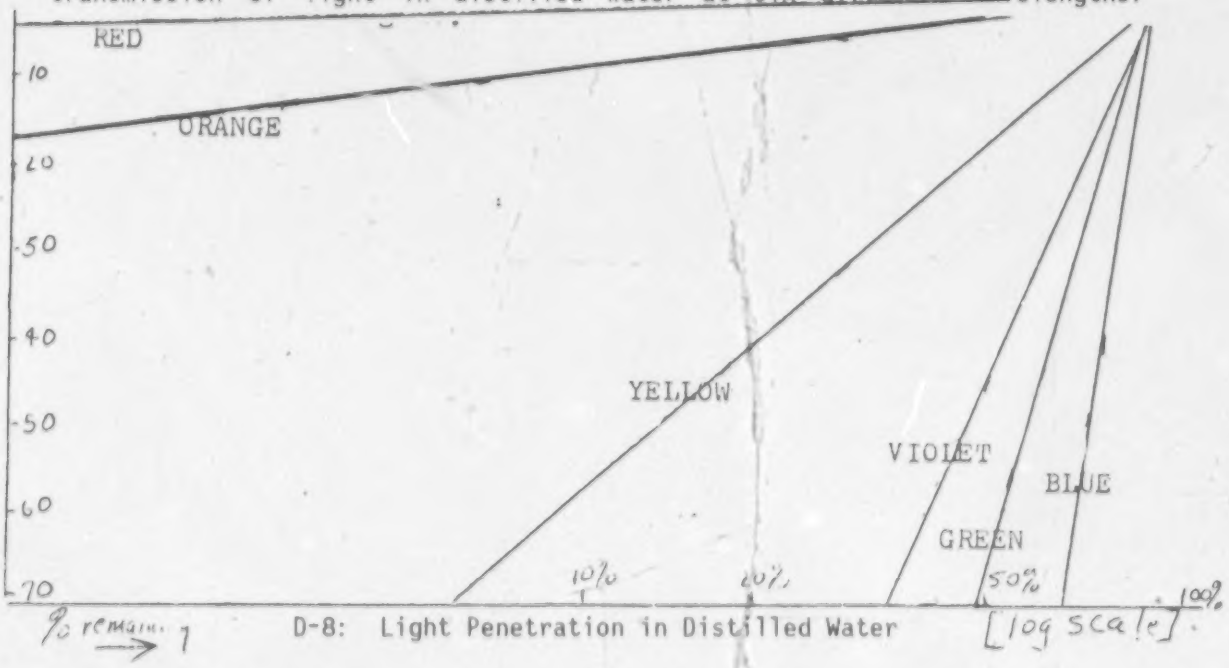
D-7: Reflection in Proportion to Sun's Angle

water. The three most important of these things are particulate matter, dissolved color, and the molecular structure of water itself.

$$n_{total} = n_p + n_c + n_w$$

n = absorption
n_p = particulate
n_c = dissolved color
n_w = water structure

Light is selectively absorbed by the factors mentioned above. Red penetrated the least and blue penetrates the most. Figure D-8 shows transmission of light in distilled water at six different wavelengths.



D-8: Light Penetration in Distilled Water

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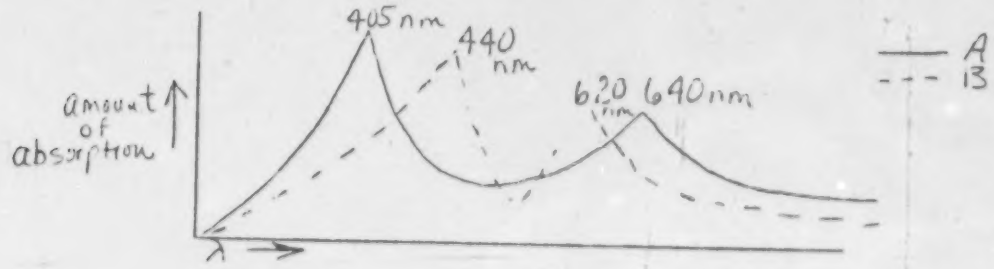
Plants and phytoplankton having chlorophyll have been able to utilize both red and blue light because of the chlorophyll molecule. Other accessory pigments including chlorophylls b, c, d, xanthophylls, and carotenes have slightly different absorption peaks. Since the phytoplankton is found at different depths having different pigments has a definite survival value. See figure D-9.

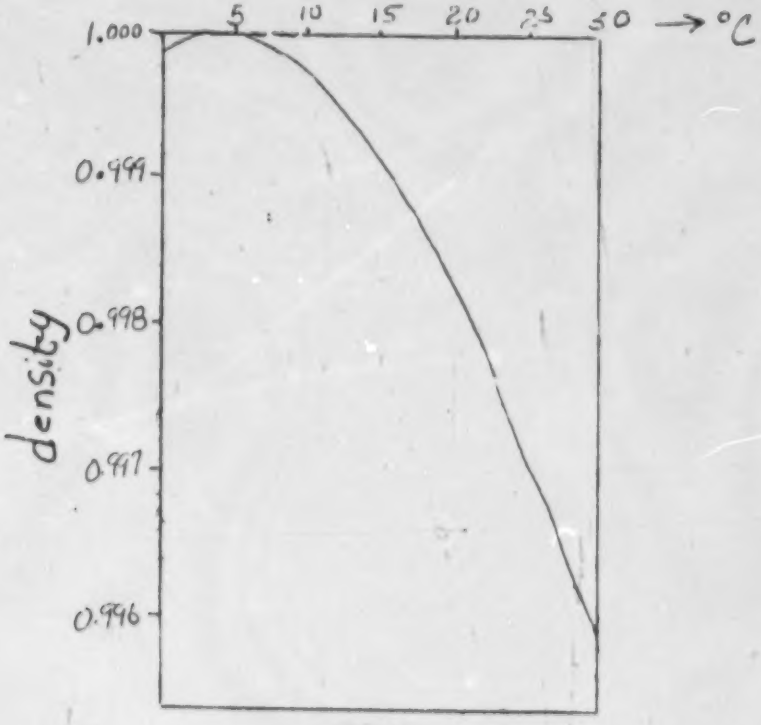


D-9: Absorption Peaks for Chlorophyll A & B

Not only plants but animals too show effects of different wavelengths of light. Mysis, the opossum shrimp, has its dominant reception at 515 nm. It is interesting to note that the area where Mysis lives has a mean reading of 515 also. Daphnia, the water flea has four different peaks. Perhaps a reason is that Daphnia is a migratory animal, moving up and down in the water.

As was mentioned earlier there are factors which cause absorption. Much of the absorbed light (half of all the sun's radiation is absorbed in the first 2 meters) is converted to heat. This heat causes the upper waters to receive a large amount of heat energy, but the lower waters receive only small amounts of heat. Most of the heat in the lower water is due to mixing during overturn and by convection and conduction currents.

Water has some interesting properties which render it unlike any other substance. Water has 4° C as its densest temperature. On either side of 4° water expands. This is shown graphically in figure D-10. This fact is important from the aspect of ice cover in winter. Since ice is less dense than water at 4° it floats.



D-10: Density of H_2O as a Function of Temperature

This ice cover is part of the idea behind thermal stratification. To understand what takes place in lakes from a thermal standpoint it would be wise to look at seasonal variations within a lake. Study of figure D-11 can help in understanding the discussion which follows.

Beginning with an ice covered lake there is colder water near the ice. As the bottom is approached the temperature will increase. When analysis of the temperatures is undertaken three distinct layers become apparent. They have been named from top to bottom epilimnion, metalimnion, and hypolimnion. These layers are the same as will be described later in consideration of the summer temperature conditions. The epilimnetic waters are near the surface an display a fairly constant temperature not varying by more than 1° C per meter.

The metalimnion is found next and here the temperature fluctuation is likely to be very rapid greater than 1° C degree per meter. The hypolimnion found next to the bottom weill also vary only slightly not more than 1° C per meter. In the winter the metalimnion is very shallow. See D-11a.

As spring approaches the ice melts. The melting ice water mixes with water in the epilimnion. This heating by the sun will continue and mixing goes deeper and deeper. At a point in the spring the metalimnion will disappear and the temperature of the epilimnion and the hypolimnion will be equal. Windy weather will help to cause total mixing of the lake water. Thi, is called the vernal (spring) overturn. See D-11b.

Overturn continues until there is a period of fairly hot weather with little wind to mix the water. This causes the upper layers to be heated very rapidly and for stratification to occur. This process gives the same layers that were noted in the winter condition. This is true stratification and the winter condition can be seen (D-11a) to be the inverse of the summer condition. Throughout the summer the heat will continue and the conduction of temperature is a slow but steady progression. This condition can be noted as the metalimnion changes shape as the temperatures of the summer are graphed. See D-11c

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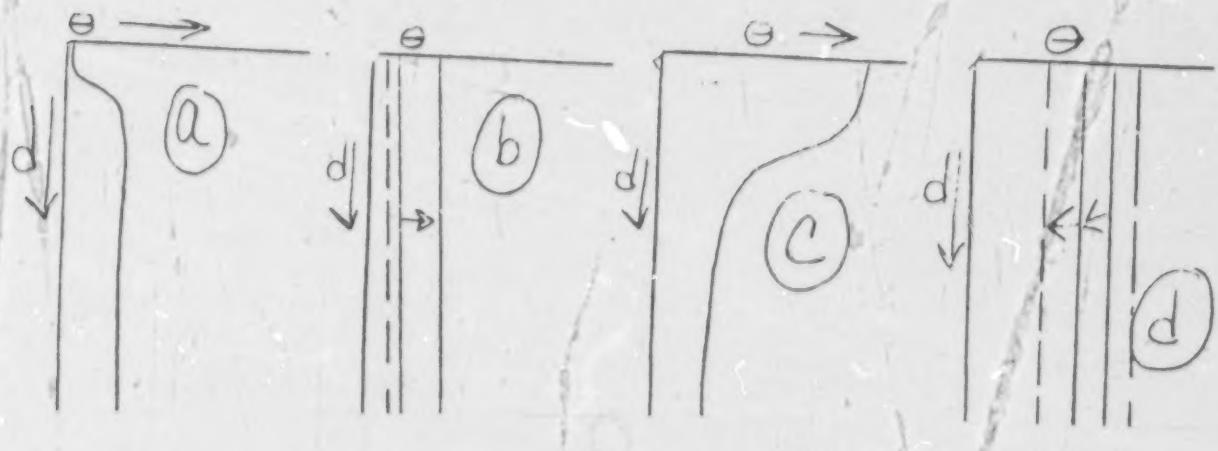
When summer moves toward autumn there is a decrease in the heating effects of the sun. This causes a cooling of the epilimnion. Cooling eventually procedes to the point where the stratification is very weak... temperature differences between the layers being very small. On a windy day the stratification is totally broken up and the fall overturn begins. Overturn continues until on a particularly cold snap the water forms a thin coat of ice, if the temperature then warms the overturn may continue, but soon the ice will become permanent for the lake and the winter stratification begins. See D-11d



D-11a-d Thermal Stratification

These diagrams represent structure of the lakes re. temperature. Important ideas include - layers of water, how and when each is formed; importance of overturn to mixing the water. Mixing stirs up the sediments on the bottom and makes more nutrients available.

Not all lakes will stratify. Several factors acting in concert determine whether or not stratification will occur. One such factor is depth. A lake must be sufficiently deep to stratify. But the depth necessary will vary according to the climate of the area. A deep lake is

needed near the equator but a much shallower lake will stratify near the poles. If this does not seem correct consult D-7 considering how the earth faces the sun.

Hutchinson proposed a system for classifying lakes according to their overturns. See figure D-12.

TYPE	DESCRIPTORS	LOCATION
dimictic	----circulates twice/yr.	---many temperate lakes
warm monomictic	--one circulation/yr	--mainly tropical > 4° C
cold monomictic	--one circulation/yr	--polar/alpine < 4° C
oligomictic	---circulation uncommon	--low altitudes, humidtropi
polymictic	--continually circulating	--high mt. lakes in tropics
meromictic	--partial mixing	--near coast or other saline source

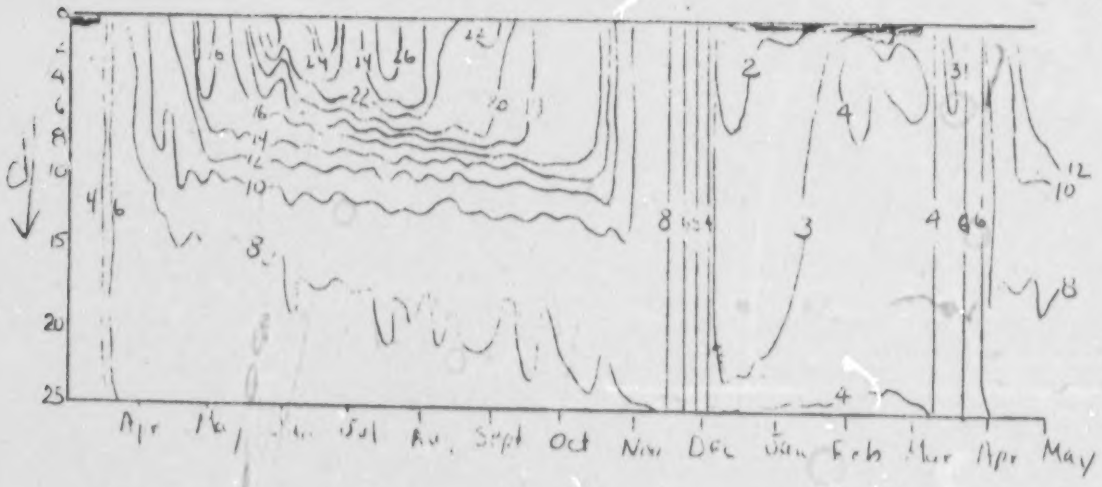
D-12 Lake Types According to Circulation

Meromictic lakes are unusual in that only a part of the lake basin mixes, there is a density difference that prevents mixing. The meromictic lake can be formed in many ways. The formation may be ectogenic - external forces supply salt to the basin--storms along the coasts; crenogenic--where salt water intrudes from the ground water; biogenic--most common occurs because of bacterial decomposition. Different terminology must be applied to the layers of the meromictic lake. They are:

mixolimnion-epilimnion
chemocline - metalimnion
monomolimnion - hypolimnion

A year long temperature record is valuable to have in the study of lake stratification and mixing. A graph of this sort is shown for Pretty Lake, Indiana. This type of graph is called an isopleth.

In the previous discussion of mixing and temperature little attention has been given to water movements. These movements are continually occuring.



D-13 Temperature Isopleth

One type of movement is the progressive surface wave. It is caused by wind drift over the water. The waves generated travel in a cytoid pattern. There is vertical movement but little if any horizontal flow. This is a relatively minor energy source in a water system.

Surface seiches (say shes) are another type of movement. These are sometimes called wind tides. Much stronger than progressive waves, these seiches an result in large displacements of water. Something similar can be seen by blowing hard across a flat pan of water There is a piling up effect on the opposite side. When the wind stops there is an oscilation. See figure D-14. The external or surface seiche is not as strong or as important as the internal sieche. Internal movements can transport heat down and nutirents up.

Foam lines, also called Langmuir waves, are possible both on surface waves and seiches both intrnal and surface. There are some types of organisms adapted for this movement. See figure D-15 for a diagram of foam lines.

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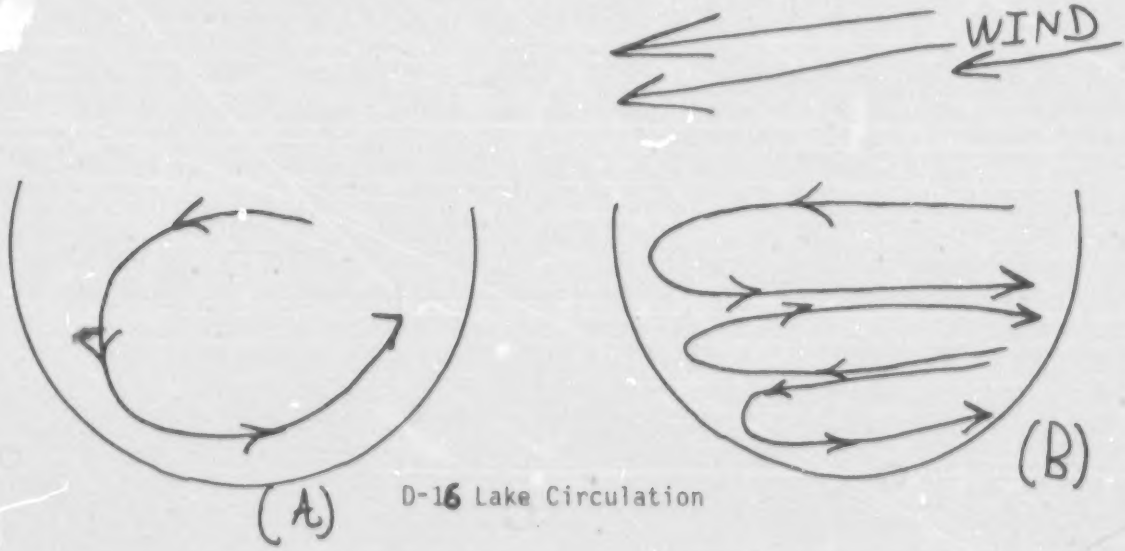
D-15 Foam Lines

In circulation of water it is important to know whether stratification exists or not. If no stratification is present the circulation within a basin can be as seen in D-16a. Straftified lakes circulate like D-16b.



D-16 Lake Circulation

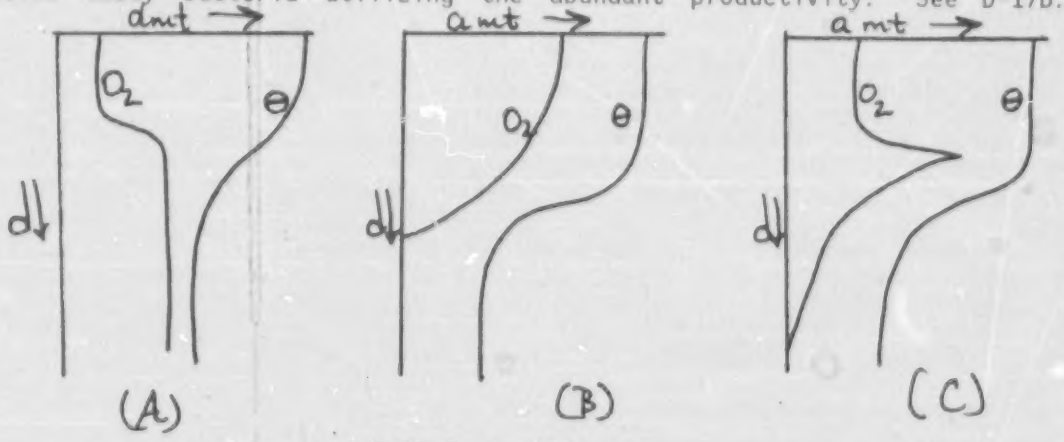
WATER CHEMISTRY

The physical aspects of lakes are important, but even more important may be the chemical aspects of water studies. These chemical parameters may be more indicative of water quality. There are many ways to approach water chemistry, but to simplify the comparisons all will be listed in terms

of the two ends of a continuum----eutrophic (highly productive) lake and oligotrophic (unproductive) lake.

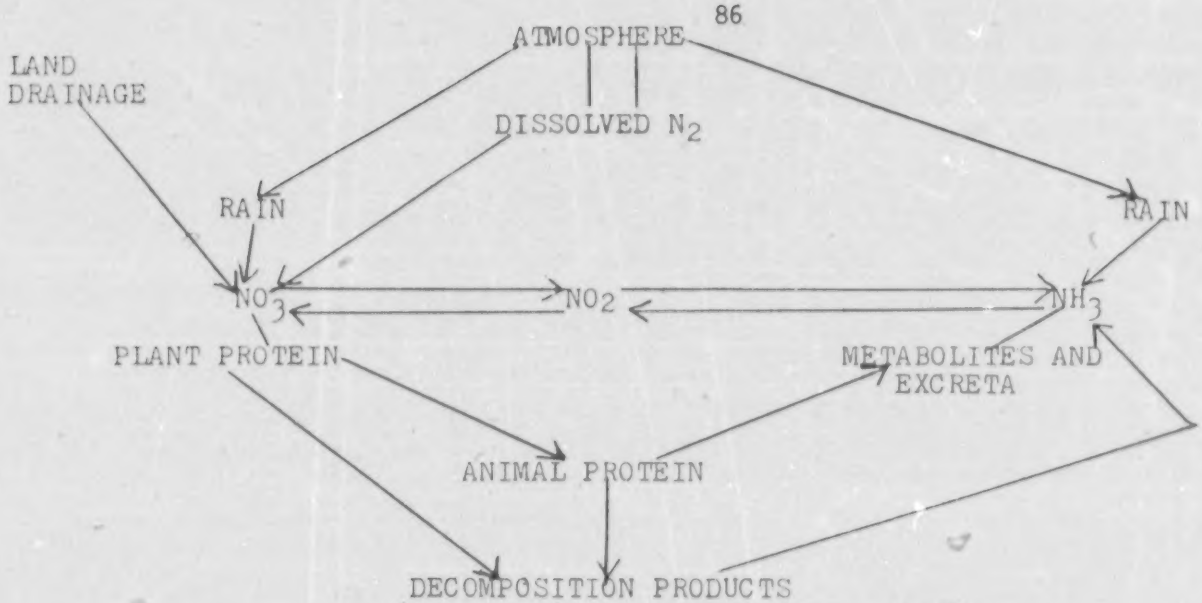
Of all water chemistry parameters perhaps the single most important is oxygen (dissolved in the water). The reason for the importance of oxygen is obvious since everything needs oxygen to carry on respiration (some bacteria, the anaerobes do not need free oxygen). A relationship of water and the oxygen soluability is that the higher the temperature the greater the soluability of oxygen.

In an oligotrophic lake the oxygen will be lower in the upper layers because of the fact that this is where the maximum usage occurs (albeit the use is small). See fig. D-17a. Eutrophic lakes show a rapid decrease in oxygen with depth. The reason for this is that in the upper waters there is a tremendous photosynthesis but none of the oxygen produced can penetrate through the stratified lake. The bottom oxygen is used up by the very active decay bacteria utilizing the abundant productivity. See D-17b.

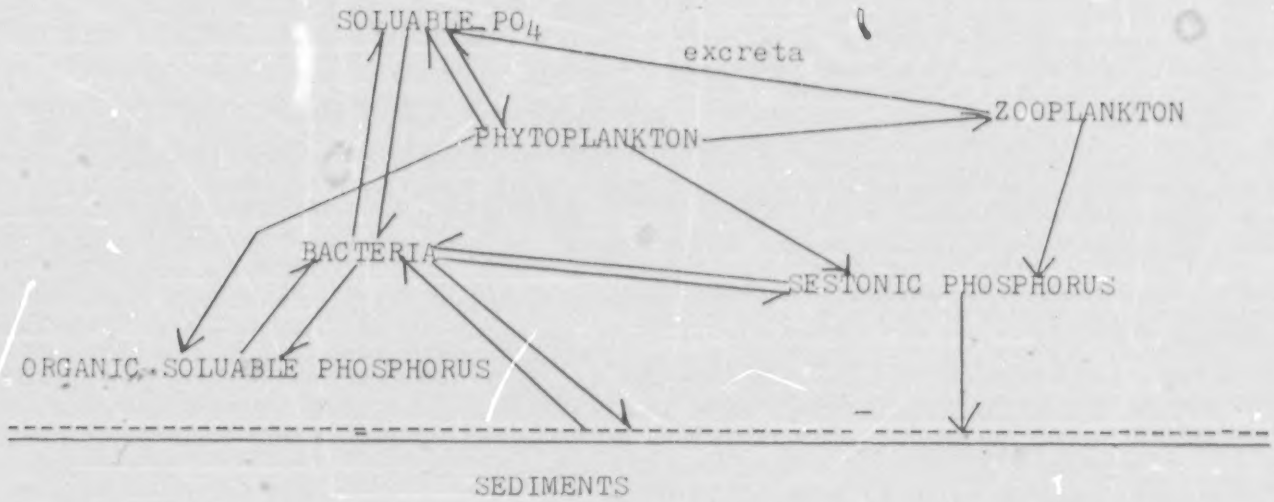


D-17 O_2 Concentration

The types of curves that are shown in D-17 are typical of curves in general. That curve in 17a is called <u>orthograde</u>. That in 17b is called <u>clinograde</u>. Sometimes due to highly productive algae there is a bulge in the curve as can be seen in 17c. This type of curve is termed a



D-18 Generalized Nitrogen Cycle

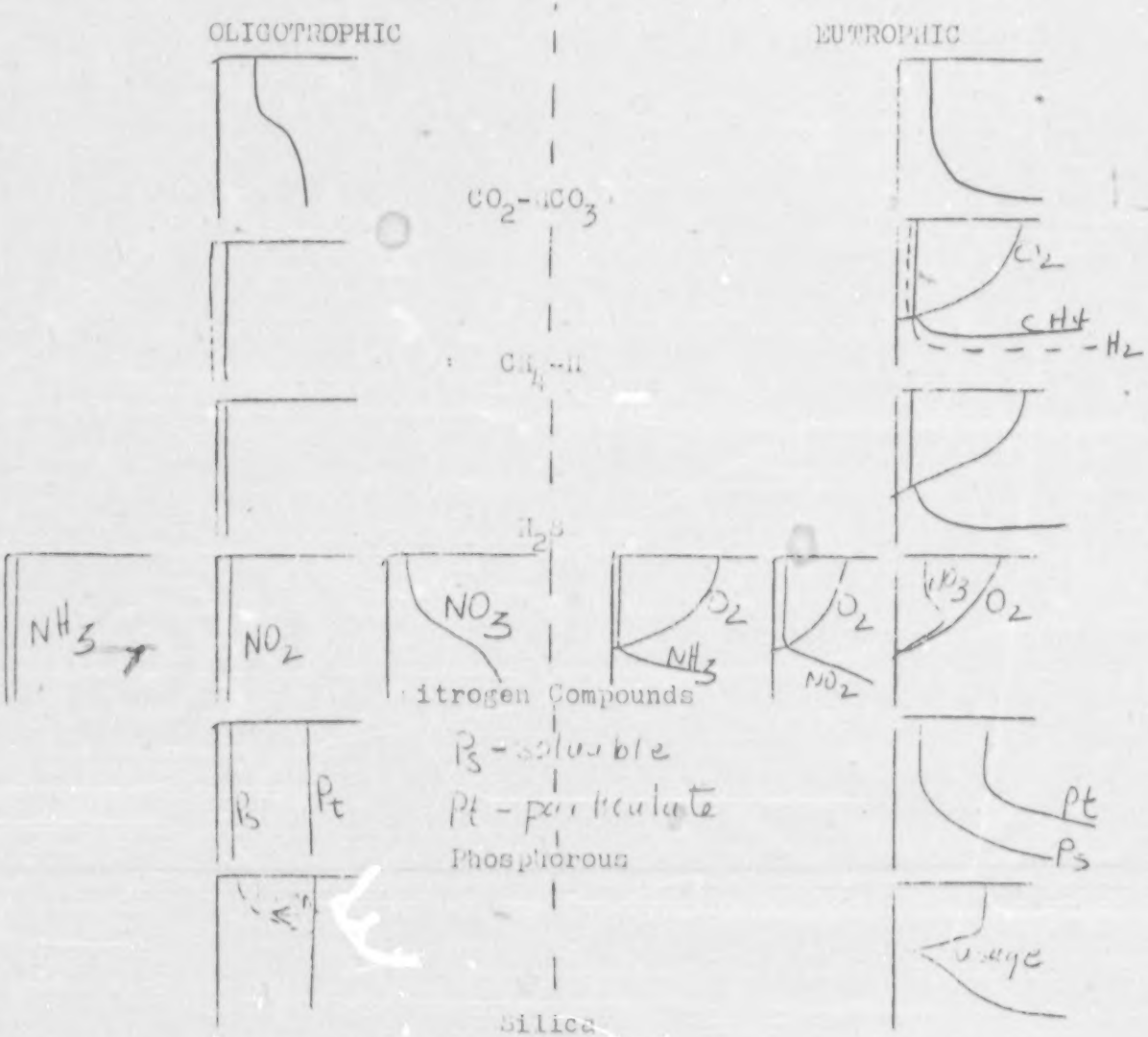


D-19 Generalized Phosphorus Cycle

positive heterograde. The shape for a negative heterograde curve should be obvious.

The nitrogen cycle and its distribution in lakes can best be understood by looking at the figure D-18. This is on the next page.

Phosphorus is another important component in lake systems. Experts disagree as to the significance of and the accuracy of data concerning phosphorus. One possible explanation is found in the diagram D-19.



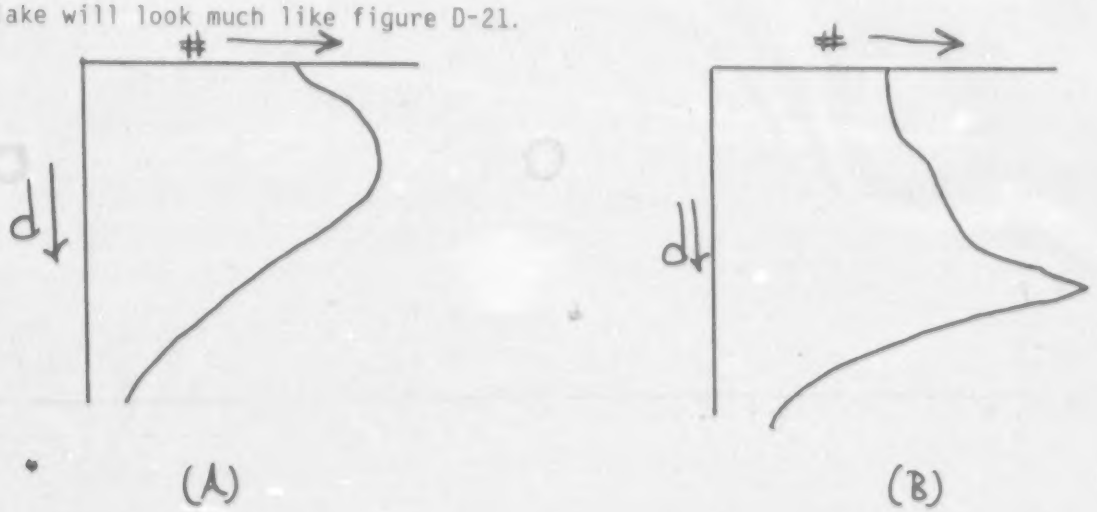
D-20 Chemical Parameters

Many other chemicals have an important role in water chemistry but their discussion to be comprehensive would go well beyond the scope of this chapter. The reader is referred to Hutchinson, Ruttner, or to Wetzel's new book. The idealized situations are found in figure D-20. The scheme of considering ends of the continuum is followed here also.

BIOTIC CHEMISTRY

Chemical and physical properties are important in determining the growth of plankton. Plankton comes in two major types-those that are photosynthetic called phytoplankton and those that are heterotrophs called zooplankton.

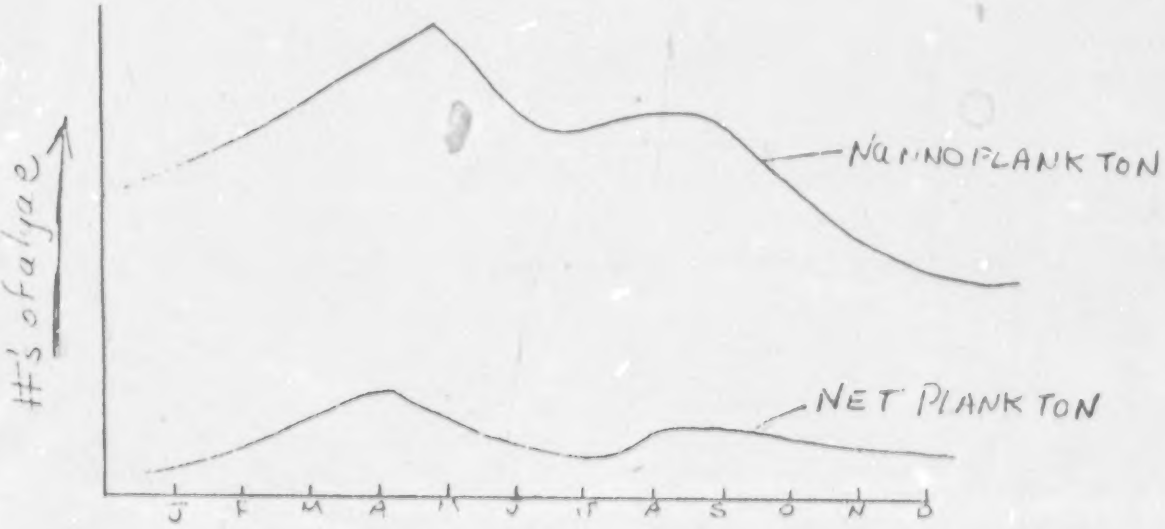
Phytoplankton is for the most part incapable of locomotion and is at the mercy of water movements. Some phytoplankters (mostly the blue-green algae) have the ability to migrate vertically. This is done through the formation of gas vacuoles. The distribution of phytoplankton within the lake will look much like figure D-21.



D-21 Phytoplankton Distribution

The decrease seen at the surface indicates photoinhibition. In other words, there is too much sunlight. The increase wtih depth (down to the metalimnion) is sometimes highly pronounced as in D-21b. This increase as can be seen rides on top of the metalimnion this water is denser than the water of the epilimnion.

Not all phytoplankton are large (i.e., 50µm called net plankton). Some are much smaller and special devices are necessary for their study. The very small algae are called nannoplankton. In most water systems the largest proportion of the algae are the nannoplankton. The realtionships in one lake can be seen in D-22.



D-22 Algal Composition-Yearly Distribution

The seasonal peaks seen in D-22 are due to a variety of causes which all interact. Some of these interacting parts are heat, sunlight, chemicals, other biota, minerals, and nutrients, to name but a few.

The other component of plankton is zooplankton. The major differences are their lack of photosynthetic ability and their increased motility.

1970083

Within the group of organisms we call zooplankton there are few of the protozoa. This should not be taken to mean that there are none, rather that the collection and identification procedures are not specific enough. Rotifers are a large component of the zooplankton, but most are small and hard to identify. The arthropods are the largest component of the zooplankton both in number and size.

One member from the Rotifera will be considered so that the reader can better understand the dynamics of the lake as the role of the rotifers relate. Keretella will be the rotifer considered because of its relative abundance. See picture in D-23.

D-23 Keretella

The size of Keretella is about 300μm in length. It feeds by a grazing or sedimentary process. Other rotifers have a centrifuge apparatus than spins food particles from the water and then they are puiled into the mouth. Reproduction in rotifers is fairly complex. There are two distinct phases to the life cycle. The life cycle for a typical rotifer is found on the following page...figure D-24.

The diagram lists several possibilities for an environmental trigger. Also on the diagram the importance of parthenogenesis should not be overlooked. This type of reproduction means that eggs develop without fertilization.

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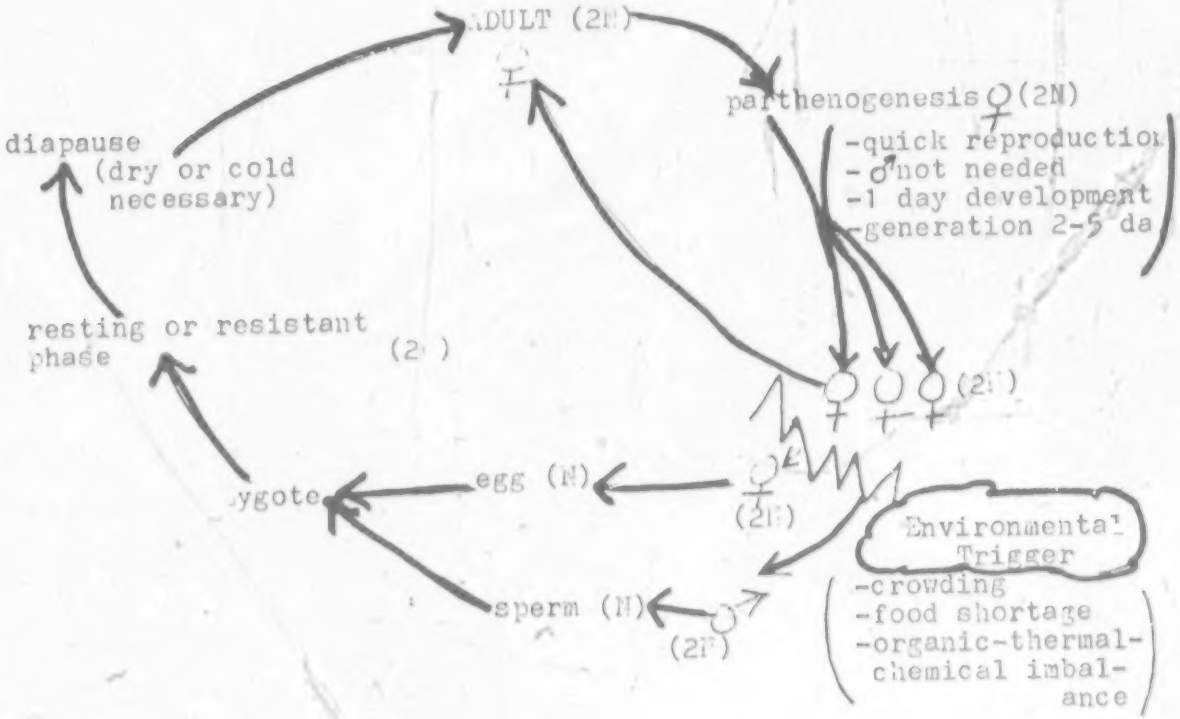
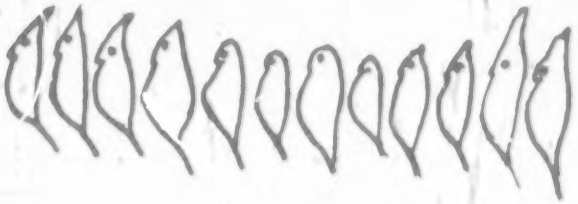
Leaving rotifers and looking at the next large group---Arthropods) The most important and interesting organism within the group is the water flea...Daphnia. Their size is between 0.5 - 4.0 mm. The abrupter appendage is used to rid the feeding groove of waste materials, excess algae, egg deposition. The life cycle of Daphnia is almost identical to the one shown for the rotifer. There is probably an evolutionary



D-24 Life Cycle of a Rotifer

significance here. Like all Arthropods Daphnia grows through shedding the exoskeleton. Each time the carapace is shed it is called an instar; there are no set number of instars in Daphnia. Generally there are 5-6 pre-adult instars, but the number for the adults has no set value.

Daphnia exhibits changes in body shape due to various environmental factors. These changes occur in a cyclic manner---in other words, in winter time the body has shape BY in the summer it has AZ but next winter the shape will be BY again. This process is called cyclomorphosis. Figure D-25 shows this graphically.

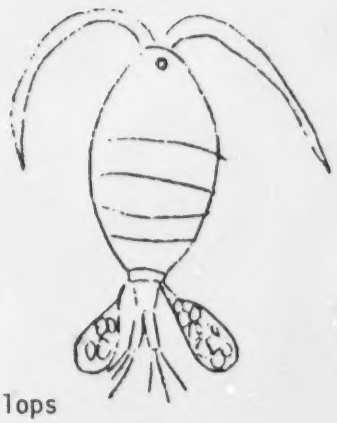


D-25 Cyclomorphosis

One other arthropod group that is important is Copepoda. There is one member that has both an interesting shape and function Cyclops. The size is about the same as for Daphnia. Cyclops is a predaceous feeder--it captures prey. The life history of a copepod would include the fact that they are bisexual; the larvae which hatch are called nauplii. The nauplii has only 3 pairs of anterior appendages but through the next 11 instars there is an increase in size and development. In some copepods the first moults may be passed in the egg. In a few cases the adult may moult. Identification is based on the appendage parts.

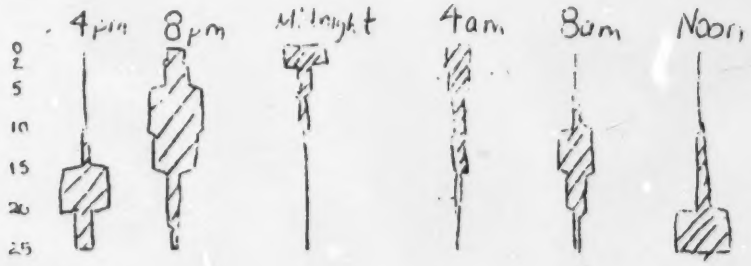
D-26 Daphnia

Cyclops is shown in figure D-27.



D-27 Cyclops

Zooplankton exhibit a diurnal migration in the water level. There are probably many reasons for this movement. But many scientists believe that light is the trigger. Views of this type of movement can been seen in the data graphed in D-28.



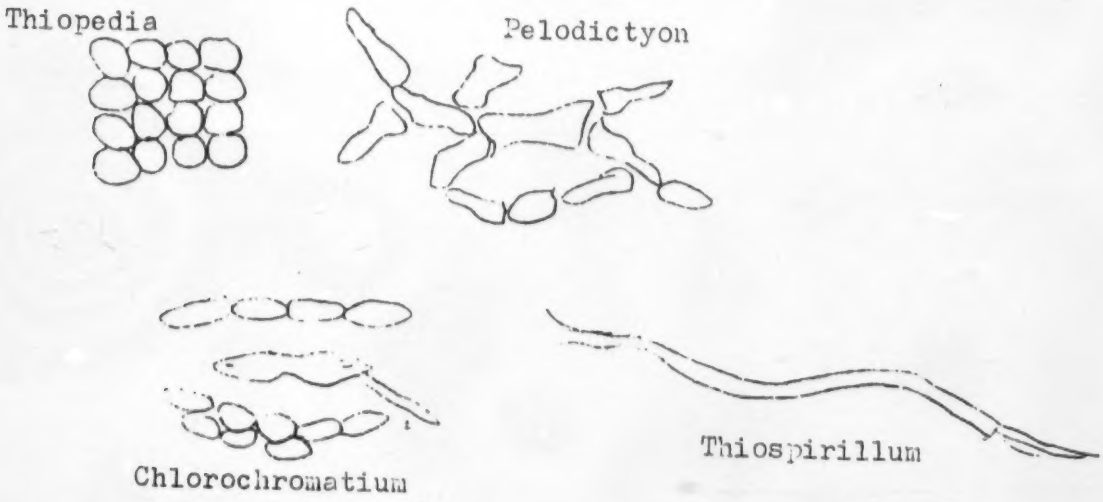
D-28 Diurnal Flux in Daphnia

A very important part of lake dynamics revolves around bacteria. Not much is known, so broad generalities are about all that can be stated. About the only bacterium that a lot of work has been done on is Escherichia coli. Most study done of the other bacteria have been cursory and shallow. The biomass of the bacteria in a lake is generally believed to be about 1% of the biomass of the phytoplankton. The importance of the bacteria as decomposers cannot be overstared. Bacteria show a seasonal flux. Thre

greatest numbers occur during the end of summer stagnation and the fewest occurring during the winter.

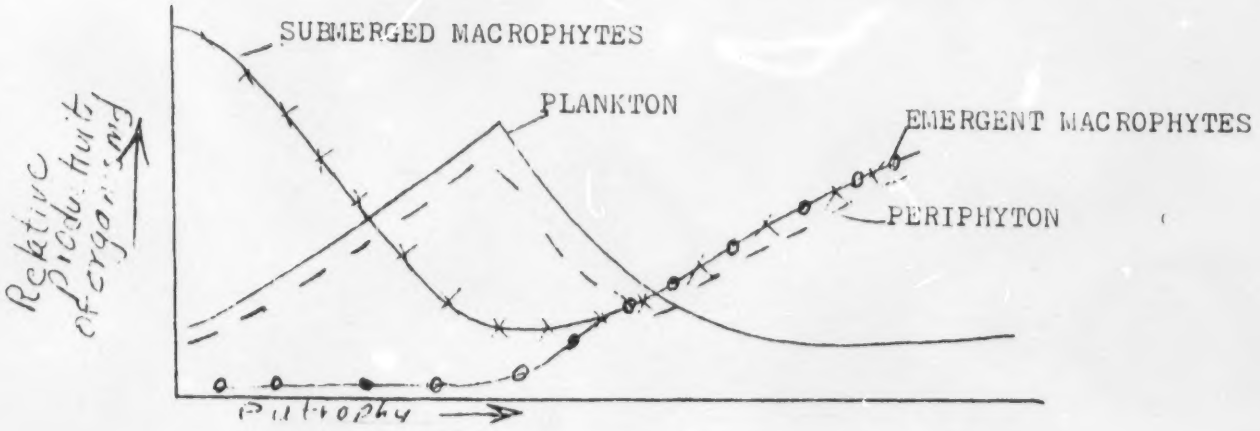
Some bacteria have the ability to chemosynthesize - that is to fix carbon using chemicals as the energy source rather than the sun. Some evidence indicates that chemosynthesis may account for 35% - 65% of the total energy budget of a lake. Some findings are even toward higher figures. Some representative types of bacteria can be seen on the following page in D-29.

The following are presentations of Dr. P. Hirsch of some of the bacterial types found in Wintergreen Lake, Michigan.



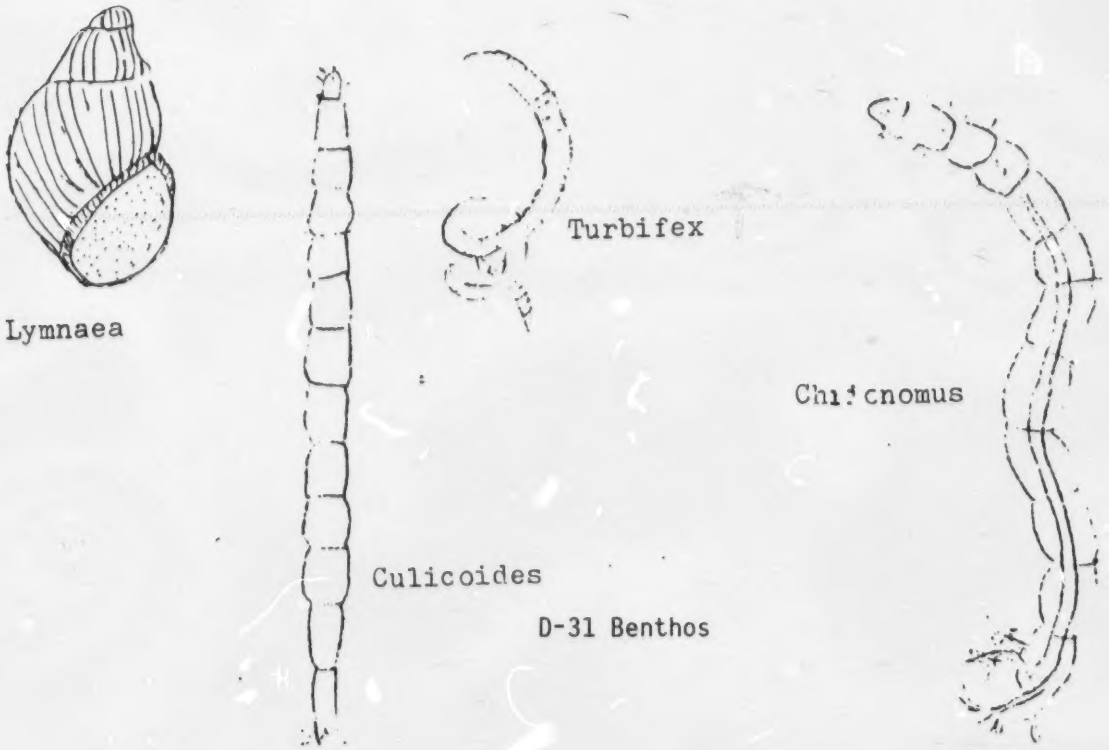
D-29 Bacteria

Another group of microorganisms are called the periphyton. The live for the most part attached to surfaces, living or dead. In some lakes 25% of the total productivity may be due to the periphyton. A relationship between periphyton and the states of eutorphy is obious when the figure D-30 is studied.



D-30 Relationships between Periphyton and Lake Eutrophy

Larger than the periphyton are the benthic organisms. The rule that the more productive the lake the smaller the diversity holds true. Most benthos are insect larvae, clams, oligochaets, etc. For a representative sample of the types see D-31.



D-31 Benthos

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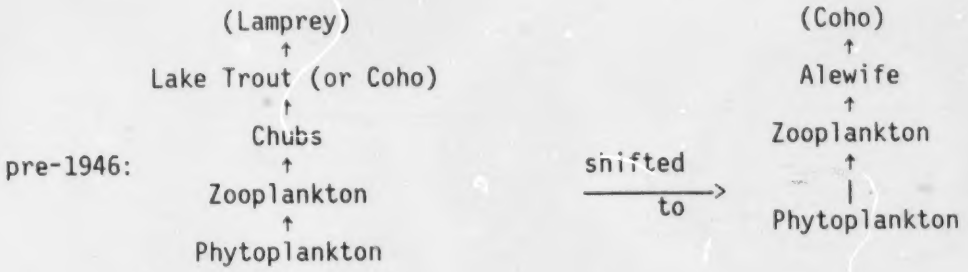
Fish are large organisms that are at the top of the lake food chains. There have been changes within the food chains in certain lakes. The changes in Lake Michigan are shown graphically in figure D-32.



D-32 Changes in Lake Michigan

There are many macrophytes that inhabit the shorelines and the bottom of lakes. Their diversity is too great to delve into in this short presentation. The reader is referred to Manual of Aquatic Plants by Fassett. The grouping of plants that inhabit the water systems can be broken down into two main categories. See figure D-33 for a breakdown of these main categories.

I. HYDROPHYTES ATTACHED TO SUBSTRATE
   1) Emergent and support themselves
   2) Free-floating leaves submerged body
   3) Submerged Leaves

II. FREE FLOATING HYDROPHYTES
   a) Totally floating mode. No attachment

D-33 Macrophyte Associations (adapted from Halfen)

LAKE TYPES

In the earlier section on water chemistry there were two divisions used to be at the ends of the continuum-ologotrophic and eutrophic. There

are two other general lake types that are important in the lake types in the temperate regions of the world. The types are bog (sometimes called Dystrophic) lakes and marl lakes.

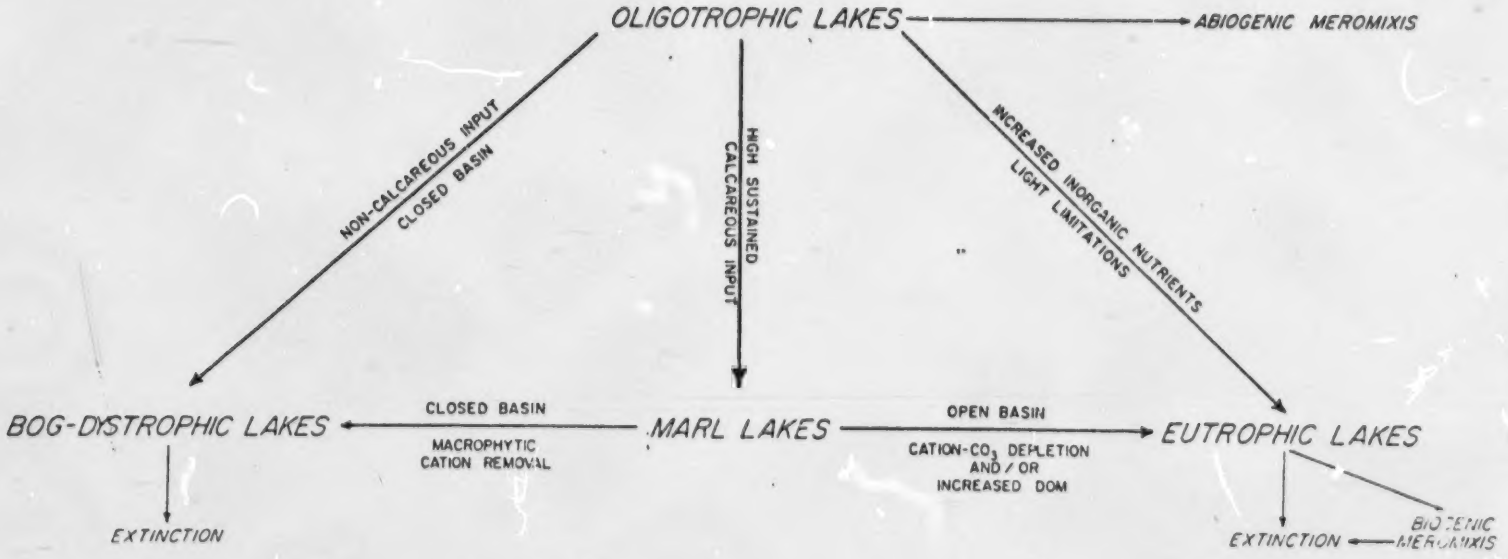
The evolution of lakes or the succession from one stage to another can best be understood by studying figure D-34 on the following page.

In a purely descriptive sense the bog lake is a stage in the succession from open water to dry land. For a more complete view see figure D-2 on page 65. The water in a bog will be slightly acid and typically have an area of Sphagnum or peat moss that surrounds the water. The lake basin will originally have a $\bar{x}$ depth of less than 18-20 m. In this type of lake the volume of the hypolimnion will be smaller than the volume of the epilimnion. There will be a large littoral zone when compared to the area of open H^2O. The open area will be sealed off from the ground water except run-off through the moss. This lake type is generally found in a closed protected basin with no major inflow or outflow and little wind action.

Temperature is a variable that seem related to depth and insolation. If the lake is deep enough it will stratify. If the lake is shallow it will show diurnal flux in temperature covering a very broad range.

Light penetration is very good eventhough the water is highly stained. The colors that penetrate best are the reds; the blues are much attenuated. The coloring in the water is due mostly to dissolved organics (mostly colloids). Turbidity is low in the dystrophic lakes.

Oxygen in the mat that surrounds the open water can disappear if the sample is taken more than a few mm deep. In the open water the oxygen fluctuates widely but is relative high. The concentration is almost always lower than in non-stained waters.


OLIGOTROPHIC LAKES
ABIOGENIC MEROMIXIS
NON-CALCAREOUS INPUT
CLOSED BASIN
HIGH SUSTAINED CALCAREOUS INPUT
INCREASED INORGANIC NUTRIENTS
LIGHT LIMITATIONS
BOG-DYSTROPHIC LAKES
CLOSED BASIN
MACROPHYTIC CATION REMOVAL
MARL LAKES
OPEN BASIN
CATION-CO3 DEPLETION AND/OR INCREASED DOM
EUTROPHIC LAKES
EXTINCTION
EXTINCTION
BIOGENIC MEROMIXIS

The pH in bogs, contrary to popular belief can vary from alkaline to acid. Why some waters are alkaline and others acid is poorly understood. The true Sphagnum bog is always acidic, however. Precipitation (pH<7) is the major water source to the bog. This coupled with the sulfur bacteria and the output of Sphagnum itself forces the pH down.

The various ionic species are poorly understood and little is known about the WHYS? What and How Much are known this data is

$Ma > K > Mg > Ca$ and $Cl > SO_4 > (CO_3)$ or (HCO_3)

Biota in a bog is highly specialized. A cross section in figure D-35 shows some of these plants and the extent of their distribution in the bog area. The most common of the plankton is the desmid. For an example of the desmid see figure D-36. There are three plankton types:

1) Euplankton - open water types
2) Facultative plankton - associated with benthos or in open water
3) Tychoplankton - from bottom or margin of mat

Zooplankton is very small in numbers in the bog. Rotifers are the most common organisms. Almost no Daphnia-or Cyclops-like zooplankton. The benthos is little known but the variety is probably limited.

Productivity in open water is probably low but if one considers the mat itself then the total productivity is pretty high. Wetzel's studies indicate that there is a large amount of carbon fixation as measured by C14 determinations. This data is contrary to the popularly held belief about productivity. The total interrelationships in a Dystrophic lake can be seen on page 102 figure D-37.

For the same type of outline that was found on the previous page for the bog-dystrophic lakes see the following pages in this chapter. Figures D-38 through D-40. The figure D-41 uses the same type of evolutionary scheme as D-34 but includes all the data in 38-40.

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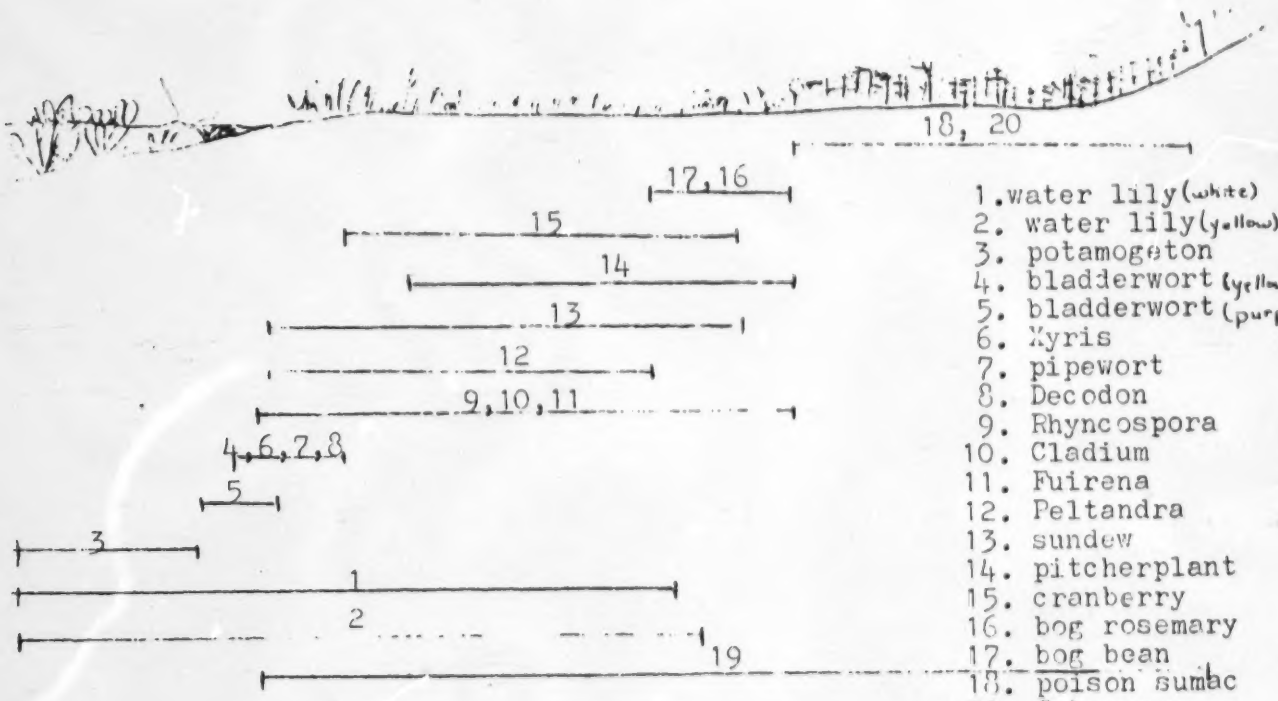
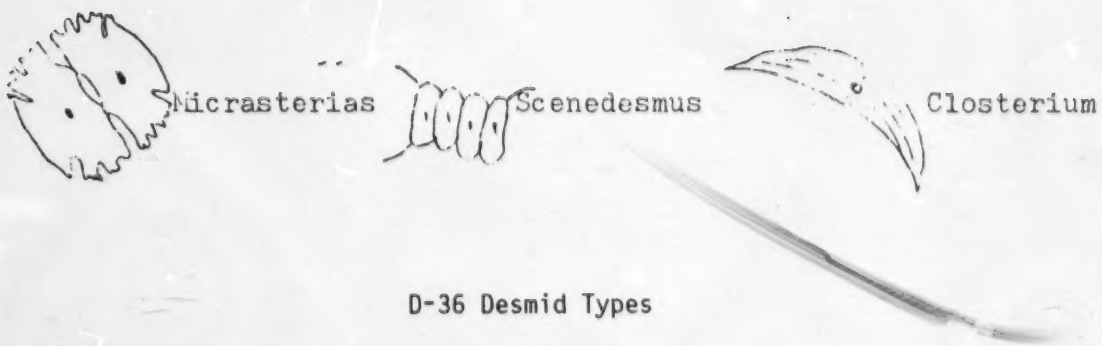
Macrophyte Zonation

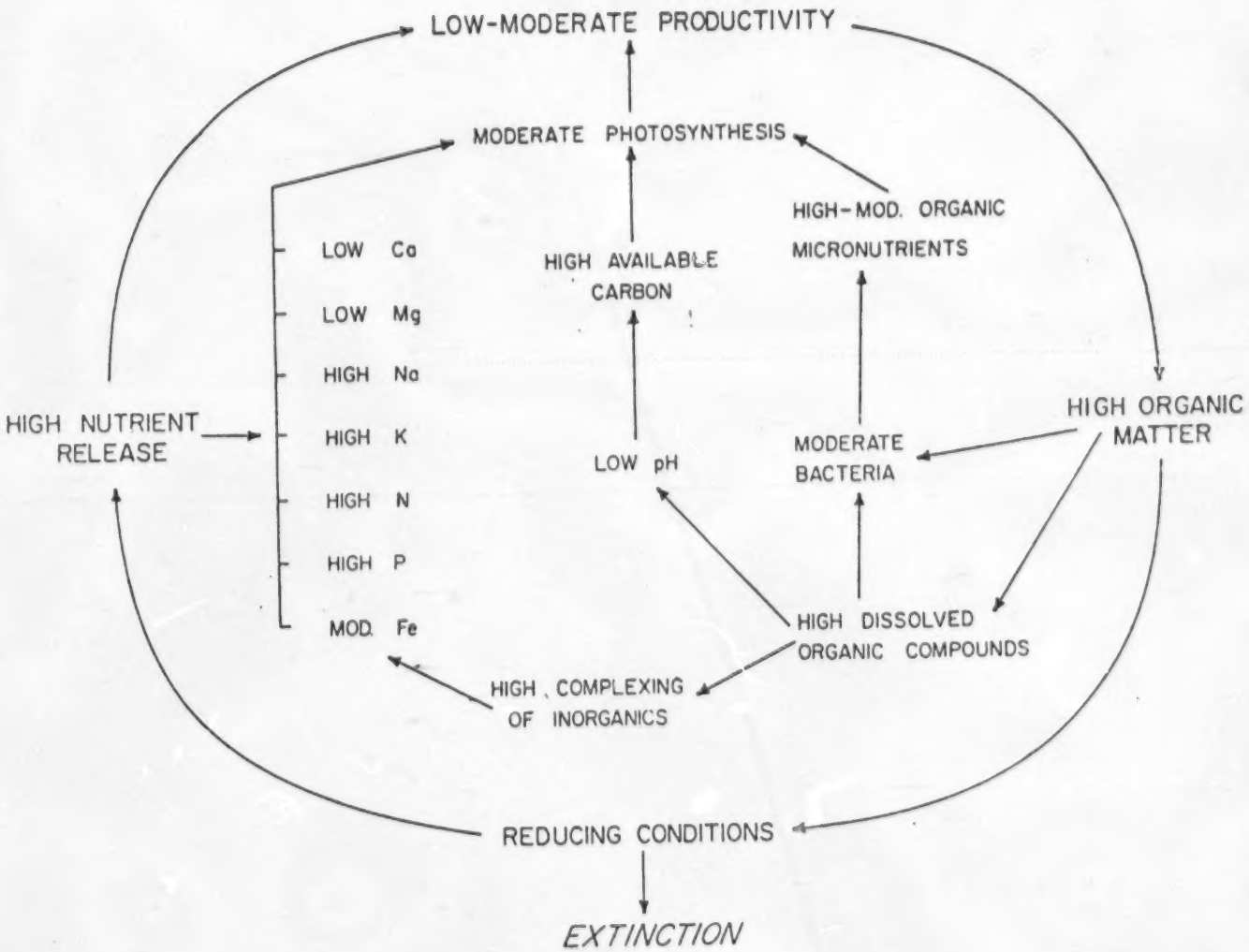


D-35 Bog Cross Section



D-36 Desmid Types

BOG-DYSTROPHIC LAKES



D-37 Bog-dystrophic Lakes

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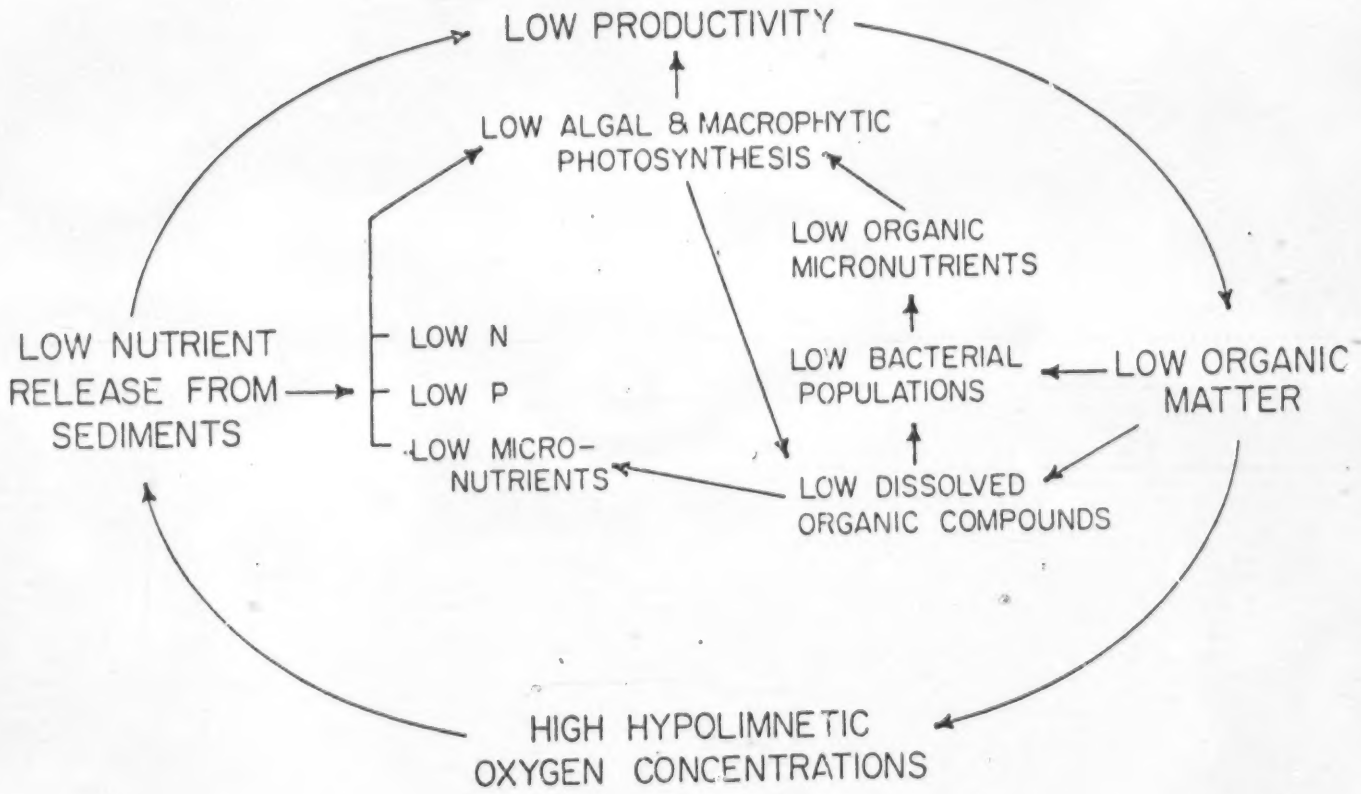
OLIGOTROPHIC LAKES



D-38 Oligotrophic Lakes

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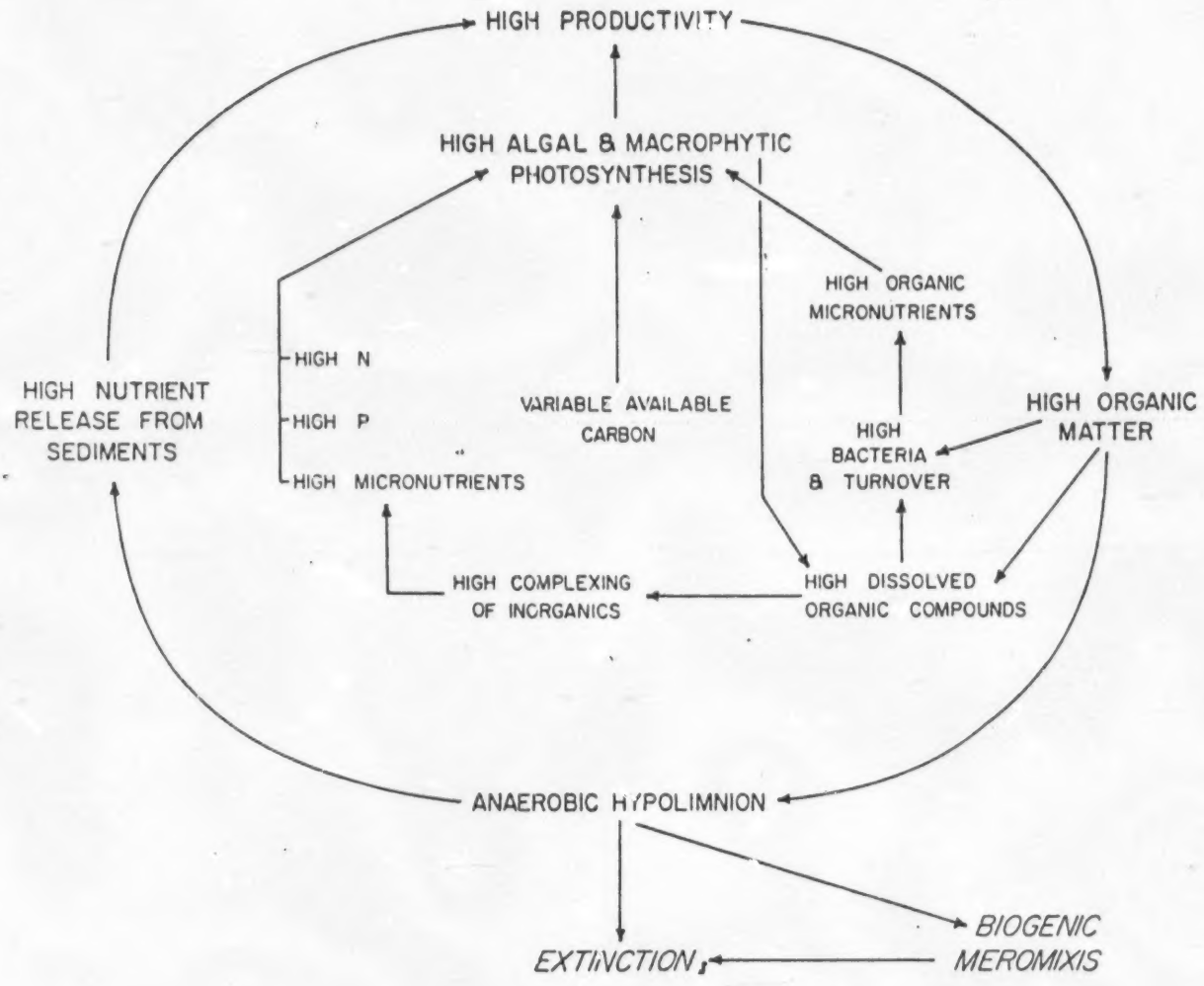
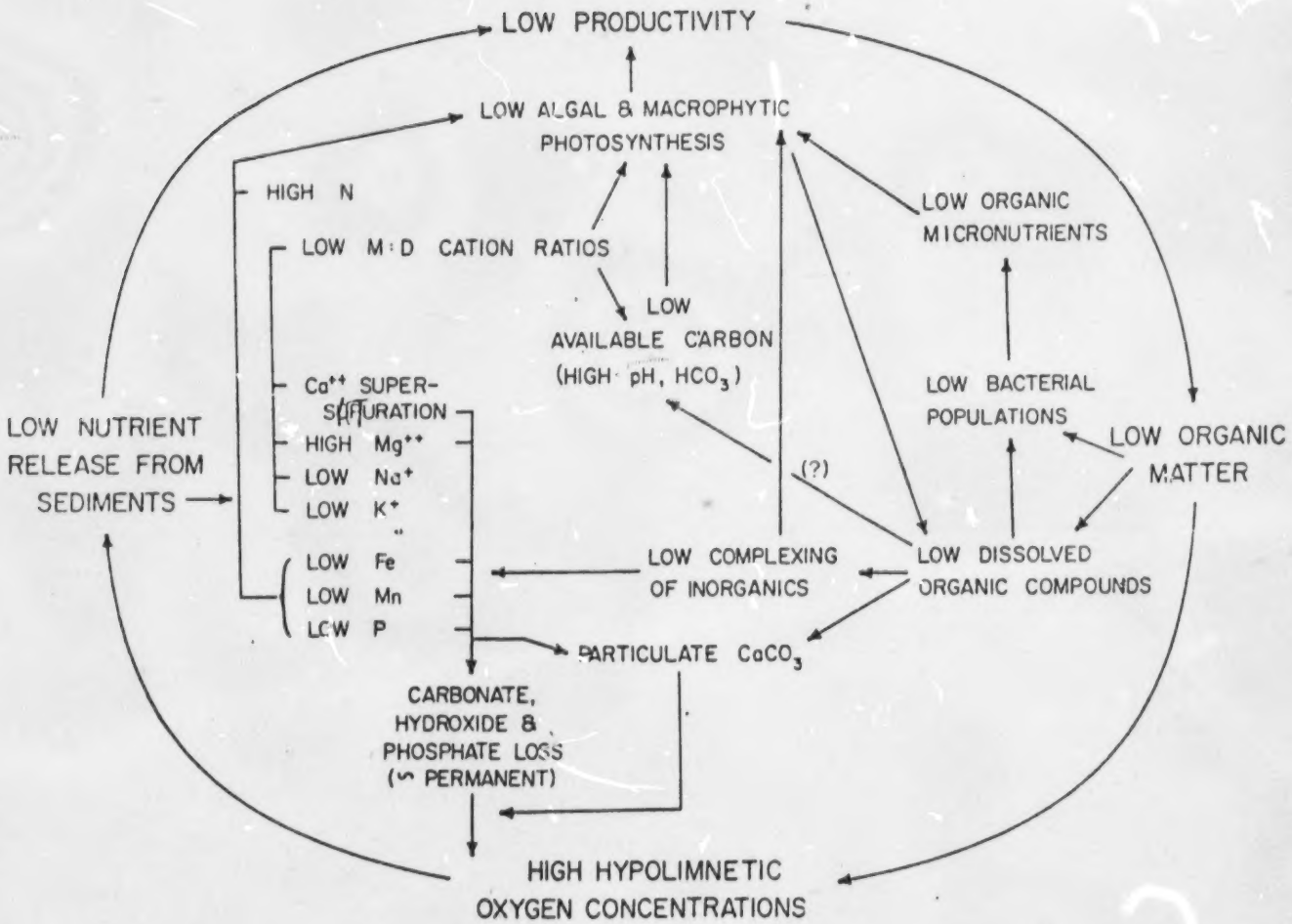
EUTROPHIC LAKES



MARL LAKES



D-40 Marl Lakes

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LOTIC WATERS

No study of water would be complete without a brief look at flowing water. There is a stream classification system that helps make understanding easier. This classification is shown in D-42.

ZONES	DESCRIPTORS
Trout zone	high elevations; rapid currents; H_2O cool; O_2 concentration relatively high.
Grayling zone	relative decrease in current; still high O_2 warmer than trout tolerate
Barbel zone	O_2 reduced at times; H_2O warm; currents are moderate to slow
Bream zone	warm water fish; sluggish currents; oxygen variable.

D-42 Stream Chart

Very little has been said about water pollution in this chapter. This as was intended since the laboratory exercises that follow are intended to make the reader aware of the problems and to arrive at their solutions. This chapter is nothing more than an introduction to water studies... LIMNOLOGY.

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Other sources will be listed in the laboratory section as they pertain to that section alone.

ENVIRONMENTAL STUDIES

LIMNOLOGY: MAJOR TEST

MATCHING

____ 1.	Father of limnology	a. oligotrophic
____ 2.	Unproductive lake	b. relic (q.v. Anal)
____ 3.	Aging or productive lake	c. Tanganyika
____ 4.	A lake that is a bog	d. Baikal
____ 5.	Lake that used to be part of sea	e. dystrophic
____ 6.	Rift valley lakes	f. depth measuring devices
____ 7.	Deepest freshwater lake in world	g. Benthos
____ 8.	Caused by a meteor	h. action spectra of chlorophyll
____ 9.	Sonar or sounding line	i. macrophytes
____ 10.	Mocimum effective length	j. Forel
____ 11.	Organisms living on bottom	k. dimictic
____ 12.	10^{-9} meter	l. phytoplankton
____ 13	Disc used to determine transparency of water	m. eutrophic
____ 14.	Red and blue peaks	n. nannometer
____ 15.	Overturn twice yearly	o. below a clinograde curve
____ 16.	Big plants	p. fetch
____ 17.	Small floating animals	q. Secchi
____ 18.	Photosynthetic floating organisms	r. Zooplankton
____ 19.	Anoxia or anaerobic	s. Singletary

MATCHING (con't)

FILL IN BLANKS

20. _____

21. _____

22. _____

23. _____

24. _____

25. _____

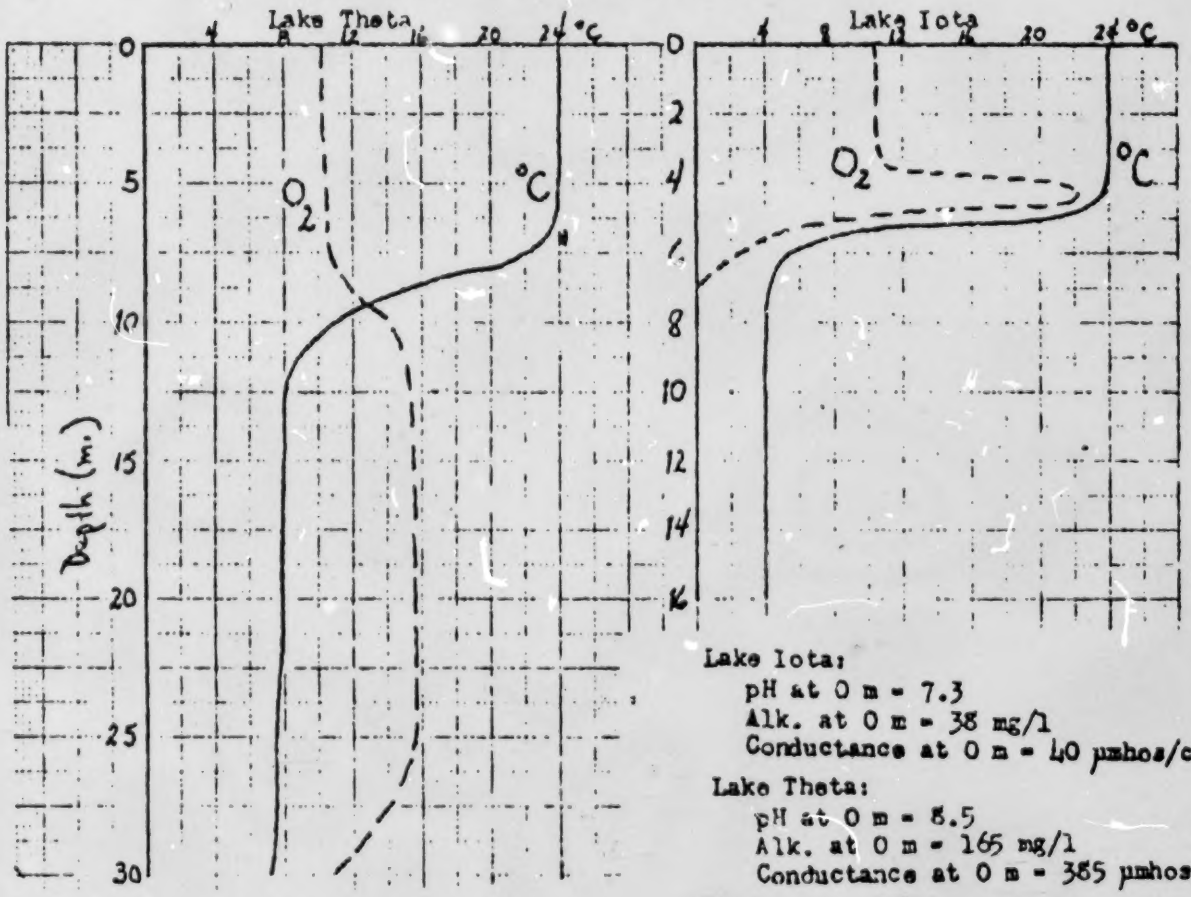
Water is able to be divided into layers by thermal stratification. The top layer is called ___(20)___; the middle layer is called ___(21)___; and the bottom layer is called ___(22)___. These layers are based mainly on ___(23)___ differences.

24. The terms seiche, currents, waves all deal with _____.

25. The Greek word limnos means _____.

"Do not become a more recorder of facts,
but try to penetrate the mystery of their origin."
Ivan Pavlov

(50 pts) 1) Two lakes in northern Indiana were examined superficially in late September during the terminal stages of thermal stratification. In addition to the O_2 and °C profiles graphed below, pH, aklalicity, and conductivity were determined as indicated (0 m only).



Lake Iota:
pH at 0 m = 7.3
Alk. at 0 m = 38 mg/l
Conductance at 0 m = 40 μmhos/cm

Lake Theta:
pH at 0 m = 8.5
Alk. at 0 m = 165 mg/l
Conductance at 0 m = 385 μmhos/cm

For each lake describe the expected vertical distribution (graphically if you wish), and a sentence or two why, of:

a) Density of the water
b) NH_3-N
c) NO_2-N
d) NO_3-N
e) SO_4^- and H_2S
f) Redox potential
g) Inorganic dissolved phosphorus
h) pH
i) Bicarbonate ion (HCO_3^-)
j) Relative buffering capacity
k) Algal biomass
l) Dissolved organic carbon
m) Particulate organic carbon
n) Alkalinity
o) Specific conductance
p) CA^{++} ion
q) Na^+ ion

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Limnology - Make-Up

For each of the following questions write the answers on your own paper. Use complete sentences and where applicable a diagram might be appropriate.

1. Outline bog succession.

2. Describe the trophic dynamic aspects of lake ecology.

3. Outline a testing regime for determining what condition a lake is in with respect to water quality.

4. Describe overturn. Describe stratification.

5. Describe the transmission of light with respect to water.

6. Describe cyclorphosis in Daphnia.

7. Outline the life cycle of a rotifer.

8. Relate the relative productivity of nannoplankton with net plankton.

9. Using a table explain the stream classifiction.

10. What is an isopleth and what is the advantage of its use as compared to a regular graph.

YOU ARE TO CHOOSE ANY SIX (6) OF THE QUESTIONS TO ANSWER. MAKE SURE YOUR NAME IS ON YOUR PAPER.

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LIMNOLOGY EXAM

GENERAL INSTRUCTIONS: THERE ARE SEVERAL PARTS TO THIS EXAMINATION YOU ARE TO FIND THE BEST ANSWER AMONG THE CHOICES GIVEN AND THEN RECORD YOUR ANSWER ON THE ANSWER SHEET IN THE APPROPRIATE PLACE. MAKE NO MARKS ON THE TEST ITSELF. IF SCRATCH PAPER IS NEEDED USE THE BACK OF YOUR ANSWER SHEET. FOLLOW THE INSTRUCTIONS YOU FIND ON YOUR ANSWER SHEET AS HOW TO RECORD YOUR ANSWERS.

CHAPTER 4

Use the KEY to match the answers to the questions.

KEY:
A. Graben
B. Kettle
C. Fluvial
D. Rift Valley
E. Relict

1. Caused by two ridges of mountains moving apart.
2. Lake Baikal is this type
3. Lake formed by a meandering river.
4. Part salt water and part fresh.
5. Occurs through a land drop along a fault line
6. Sometimes called "ice block lake"
7. Caused by the weight of a glacier
8. Plunge pool lakes are of this type
9. Caspian Sea is this type
10. Lake Tanganyika is this type.

In the following questions use the KEY:
A. Birge/Juday
B. Hutchinson
C. Lauff
D. Wetzel
E. Forel

11. Director of the Gull Lake Biological Station at Michigan State U.
12. Wrote Treatise of Limnology
13. Father of Limnology
14. Foremost practicing limnologist in the U.S.A.

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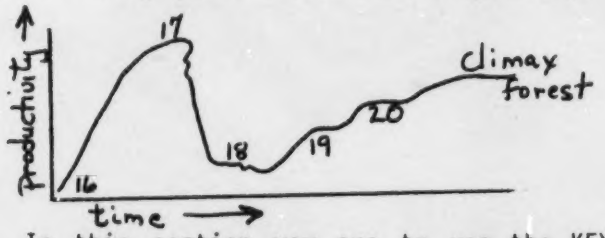
Limnology Exam (con't)

15. Founded a strong school of water studies at Wisconsin.

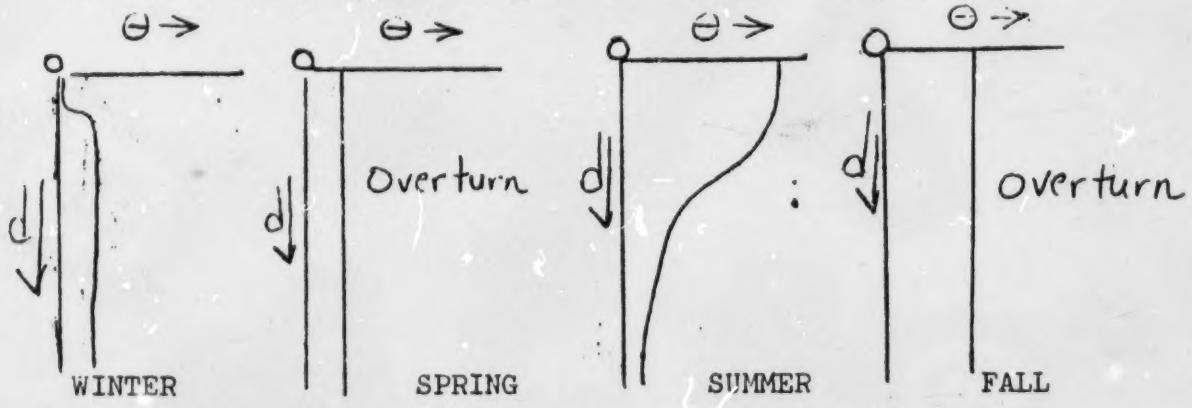
In the following questions use the diagram and the follow KEY:

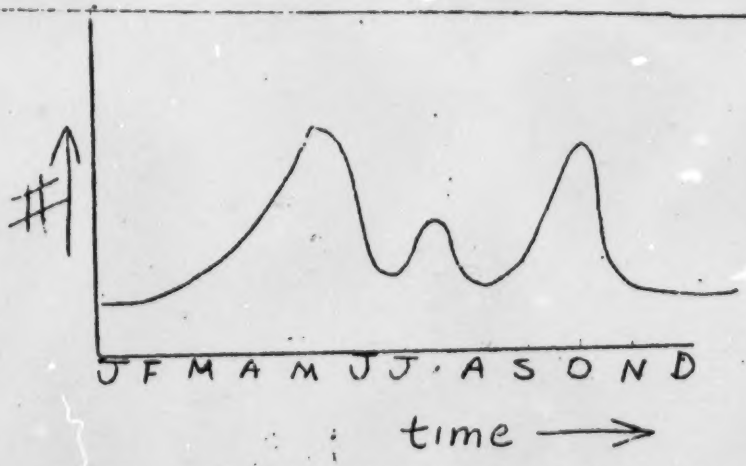


A. oligotrophic
B. senescence
C. bog mat
D. eutrophic
E. bog forest

Note: In this section you are to use the KEY to label the places on the diagram correctly.

Using the following five diagrams for data answer the questions using the KEY: A. conclusion justified by data B. conclusion not justified.





21. There is a positive correlation between overturn and algal growth.

22. All algal growth ceases during winter stratification.

1970083

Limnology Exam (con't)

23. The highest peak of algal growth is in the summer.

24. Temperature change seems to be accompanied by algal growth.

25. Algal growth is limited to the epilimnion in the summer.

In the following section use the KEY:

A. epilimnion
B. metalimnion
C. Hypolimnion

26. Warmest area in summer

27. Warmest area in winter

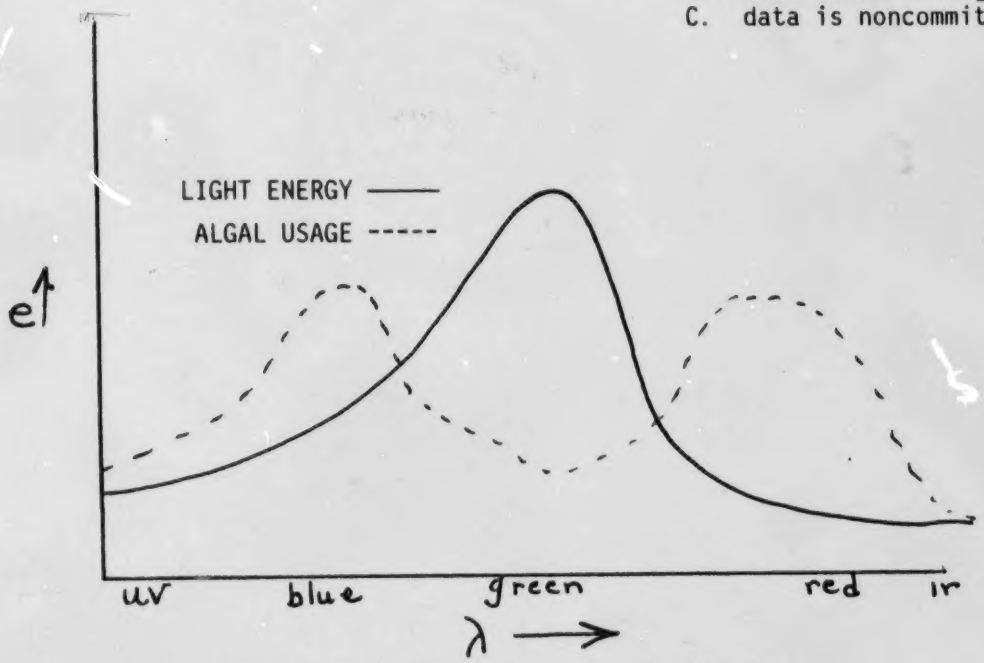
28. Where most photosynthesis occurs

29. Area of rapid temperature change (thermocline)

30. Area of densest water

In the following section use the diagram and the following KEY:

A. data seems to indicate
B. data seems to negate
C. data is noncommital



31. Algae seems to avoid the most energetic light.

32. Algae are green in color.

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33. Utilization peaks are at blue and red for the algae.

34. Light energy is fairly constant throughout the visual spectrum.

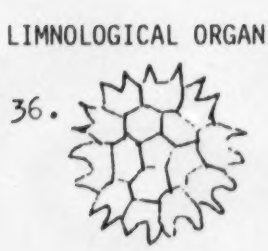
35. Blue algae and red algae would be the most successful in a competition with green algae.

The final 10 questions in this section are identifications of various aquatic organisms. The following key will help you.

KEY:
A. phytoplankton
B. zooplankton
C. neither of above

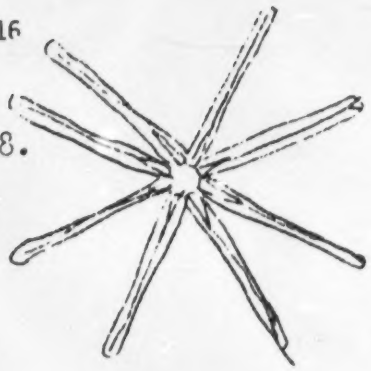
LIMNOLOGICAL ORGANISMS

36.



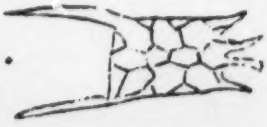
37.

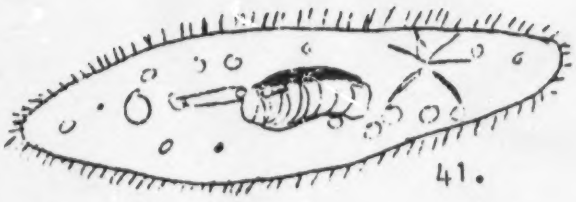
38.



39.

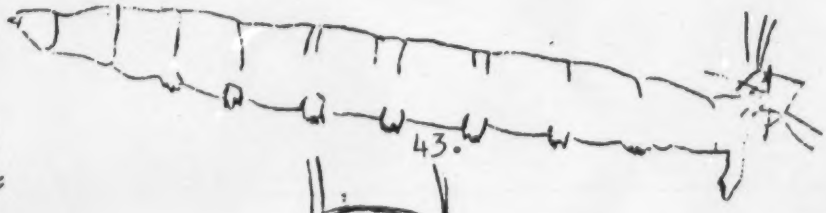
40.





41.

42.



43.

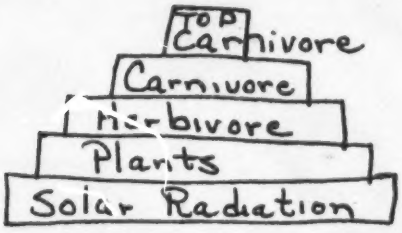
44.

45.

LIMNOLOGY TEST #2

Answer all questions by recording your answer in the proper space on the answer sheet. DO NOT mark on this test!!

Use the diagram to answer the following questions:



Energy Transformations within a System

A. Statement is true and supported by data
B. Statement is false as shown by data
C. Statement is true but not supported
D. Statement is false but not shown

1. More than two levels of carnivores may correctly be shown in any food diagram.

2. Carnivores capture about 10% of the food substance from any previous level.

3. Of all the levels shown... solar radiation has the greatest amount of energy.

4. There is a decrease in both numbers and energy as one ascends the pyramid.

5. In lake systems this diagram must be verified in each system if accuracy is to be assured.

6. As the sun's incident angle increases the reflection

   a. increases
   b. decreases
   c. stays constant
   d. varies with latitude

7. Which of the following is NOT a factor in the absorption of light in H_2O?

   a. particulate matter
   b. water structure
   c. dissolved color
   d. all ARE factors

8. If it is known that MYSIS has a domination light reception at 515 nm it would be most logical to assume Mysis

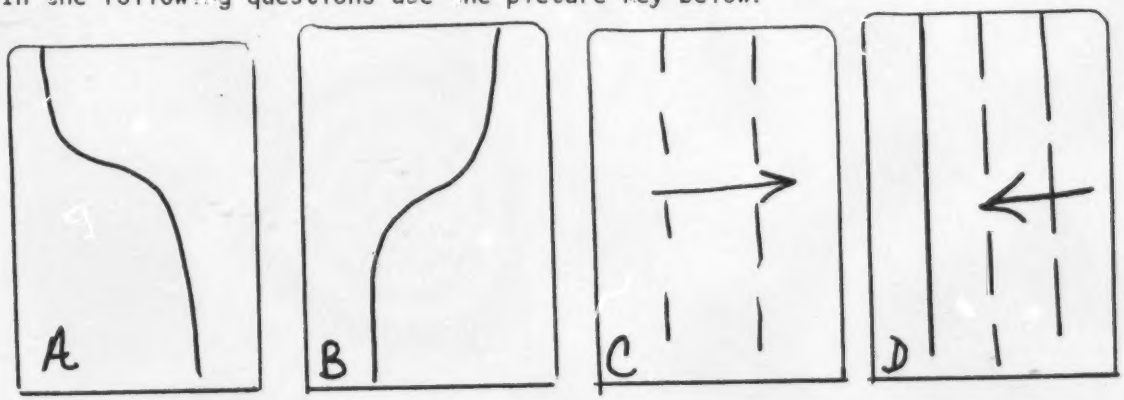
   a. is generally found near 515 mn
   b. is found near the surface
   c. is generally found near 515 nm
   d. none of the above are logical

Limnology Test #2 (con't)

9. The fact that ice floats in H_2O is taken to indicate

a. water is denser than ice
b. ice is denser than water
c. ice is larger than water
d. hydrogen bonding takes place in ice

In the following questions use the picture key below:



10. Which diagram shows stratification in the summer?

11. Which diagram shows winter stratification?

12. Which diagram would be seen in early November?

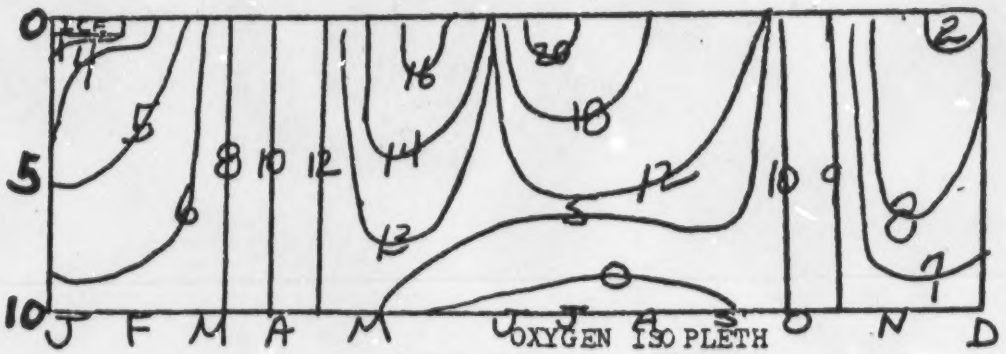
Limnology Test #2 (con't)

13. Which diagram would be seen in early April?

14. Which diagram(s) would be missing in a polymictic lake?

15. Which diagram(s) would be missing in a dimictic lake?

Use the following Isopleth to answer the following questions:



16. What month shows spring overturn?

17. What depth does 0% oxygen occur in during the month of July?

18. What is the maximum period of life on the bottom (in months)?

19. What is the effect of ice on the concentration of oxygen? (none, increase, or decrease)

20. What is the type of mixis represented by this graph?

21. Which of the following is most productive in a lake system?

a. net plankton
b. sestonic plankton
c. nannoplankton
d. zooplankton

22. The fact that zooplankton are found at different water levels during different parts of the day means

a. they migrate
b. currents fluctuate
c. light intensity changes
d. none of above

23. Cyclomorphosis is a term applied to Daphnia because

a. changes occur in the reproductive cycle
b. there are changes in the helmet shape
c. there are seasonal changes in body form
d. none of above

Limnology Test #2 (con't)

24. Bacteria have what function inlake systems

a. decomposer
b. producer
c. polytorph
d. a and b

25. Which one graph would be of the most use in determining whether a lake were eutrophic or not?

a. depth
b. temperature
c. oxygen concentration
d. pH

26-28. Diagram the life cycle of a rotifer.

29-30. List the areas in a lotic system. There are four.

31-33. Outline macrophyte succession from shore to center of lake.

EXTRA CREDIT: SKETCH A CROSS SECTION OF A BOG

LAB D-1 OLSON'S MORPHOMETRIC TECHNIQUE

Purpose: To obtain data concerning relative amount of water at each depth; to determine lake perimeter.

Materials: morphometric map, grid ruler

Procedure: Follow each of the following steps carefully and you will be rewarded with accuracy.

1. Get the morphometric map for your lake.

2. Place a square grid over your map and affix it so that it does not move. This grid may be an overlay of plastic or a ruled-on grid.

3. Determine through measurement or calculation

   (g) = grid spacing (u) = grid equivalent on map scale (a) = $(u)^2$

4. Each intersection of the horizontal and vetical lines will fall at some depth within the lake map. Note: Those intersections which fall outside the lake basin are at 0 depth. Any intersection which falls on a depth line must be interpreted by the observer. As you read across the horizontal lines prepare a depth matrix by listing the depths that are noted in a tabular form.

5. Using the matrix prepared in #4 above count the number of changes per line both in the vertical and horizontal directions. A change from the purpose of this lab is to or from zero. Note that a change DOES NOT occur in 1 - 2 or 1 - 8. In the line of a matrix like 0-1-2-4-0-1-0 there are four (4) changes. The number of vertical and horizontal changes when added is equal to the value (I).

6. Solve the formula

$$S = (I)(0.785)(u)$$

S = lake perimeter
I = changes computed in line #5 above
0.785 = constant value
u = grid equivalent computed in #3

7. Using the matrix prepared in number 4 above prepare the follow instructions closely.

DEPTH-VOLUME TABLE

A	B	C	D	E
depths listed in matrix	frequency those numbers	(A xB)	(B x a) This gives surface area	(c x a) This gives volume of H_2O at a particular depth

**Note (a) in columns D and E is the same (a) as in number 3 above.

SEE SAMPLE ON BELOW.

given:

g = 1 cm
u = 50 m
a = 2500 m^2

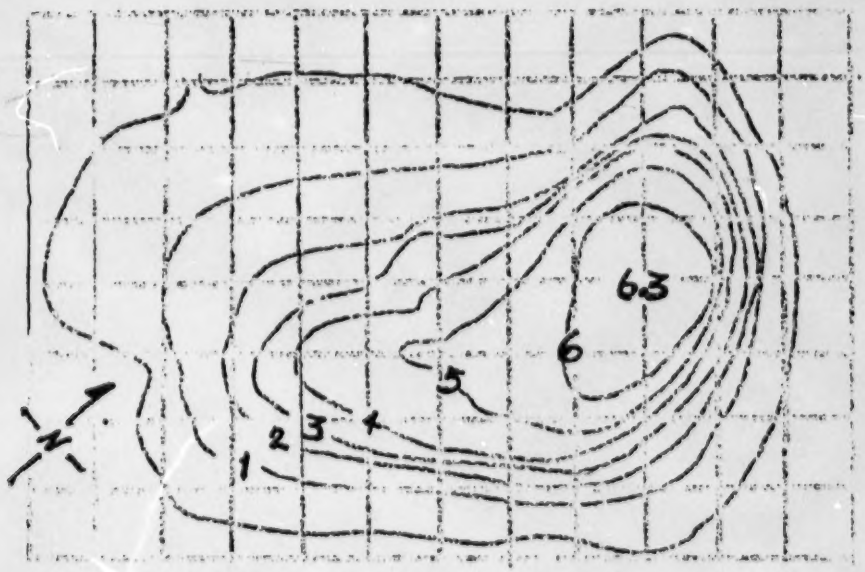


Diagram of Wintergreen Lake, Michigan

8. Solve numbers 6 and 7 from previous page using this lake.

LAB D-2 ANALYSIS OF LAKE GRAPHS

Purpose: To learn graphing techniques and analysis of the data.

Materials: regular graph paper, colored pencils

Procedure: Lay out your graphs so that you are ble to get about four graphs per page of graph paper. Make sure that you keep the scale on your graphs accurate.

Plot each of the data given and then using your book explain the variations in the plotted data from the expected. The lake that is shown in the data below is eutrophic.

Make sure that each graph is accurately labeled.

WINTERGREEN LAKE 24 JULY 1972

Depth	Temp.	ppm O_2	pH	Fe_{total}	NH_4^+	NO_2	NO_3	SiO_2	PO_4
0	26.5	8.4	8.9	0.07	0.66	0.01	0.14	0.2	0.07
1	26.5	8.4	8.8	0.06	0.48	0.01	0.14	0.0	0.04
2	26.0	7.2	8.7	0.07	0.52	0.01	0.14	0.0	0.04
3	20.6	6.8	8.5	0.08	0.62	0.01	0.22	0.03	0.06
4	15.5	1.4	8.1	0.13	0.72	0.01	0.22	1.0	0.06
5	11.0	0.0	7.2	0.30	2.99	0.02	0.46	2.3	0.32
6	9.1	0.0	7.0	0.44	6.04	0.08	0.46	5.5	0.44

LAB D-3 ANIMALS OF THE POND

Purpose: To identify and order the collection of samples from the pond.

Materials: plastic containers, microscope slides, cover slips, droppers, microscope, plankton net, pond life key

Procedure: Use the plankton net and collect samples from the lake.

Place the samples collected into either the plastic containers or bags.

Make slides of the collected materials and observe under the microscope.

Using to dichotomous key identify the organisms that you find that beong to what we call the zooplankton.

Group the animals according to the way that they move, size, and color.

Prepare a phylum distribution chart based on the number of organisms that are found in the water.

Notes to the teacher: Many good keys can be had free for the asking from the EPA. They are listed below:

"An Introduction to the identification of Chironomid Larvae," EPA, 1973, Cincinnati, Ohio 45268

"The Role of Benthos and Plankton Studies in a Water Pollution Surveillance Program," J. B. Anderson, et al, EPA, 1965, Cincinnati, Ohio 45268.

LAB D-4 PLANTS OF THE POND

Purpose: To collect and quantify the phytoplankton from a lake.

Materials: Millipors filteration apparatus and filters, slides, immersion oil, collection bottles, and a Van Dorn or similar bottle, I_2KI, algal key

Procedure: Collect water samples from the various depths that your teacher instructs.

This collection will be done with the Van Dorn or similar bottle, this is so that the purity of the sample can be assured. After the sample is taken a quantity of it should be filtered onto a Millipore filter (45 µm pore size). This quantity will be from 25-100 ml depending upon the clarity of the water... the clearer the water appears to the naked eye the more that should be filtered. The I_2KI should beaded as the material goes through the filter. After the filter has dried... quarter it and place the dried filter onto a drop of immersion oil that has been placed onto a microscope slide. Place a coverslip over this material and you are ready to observe the material under the microscope. A count of the organisms should be taken and using the key of algae, identify them. To calculate the total number of organisms per ml use the following conversion factors:

#organisms/litre = #/square x 54.542 x 10 (100 ml filtered)
54.542 x 20 (50 ml filtered)
54.542 x 40 (25 ml filtered)

Of course the plants of the lake are not limited to the phytoplankton but also there are many macrophytes that are around the edge and also grow into the water itself. The study of macrophytes are best left to the people like Fassett who has written a very important book called AQUATIC PLANTS. There is another guide that is fairly helpful called Pond Life it is in the Golden Book Nature Series, Ed. Zim.

Notes: The following materials will prove of great help in studying this material:

Methods of Collection and Analysis of Plankton, Federal Water Quality Admin., 1970.

Use of a Floating Periphyton Sampler, Federal Water Pollution Control Admin., 1970.

"A Field Key to the Algae," ERIC file included in appendix to this lab.

"Periphyton," Standard methods, 13th ed., 1971.

LAB D-4 PLANTS OF THE POND (con't)

"Aquatic Weeds," Science, 7 November 1969. pp. 699-708.

"Factors Affecting the Growth of Two Green Algae," The American Biology Teacher, November, 1974, pp. 494-495.

A Guide to the Common Diatoms, U.S. Environmental Protection Agency, 1971.

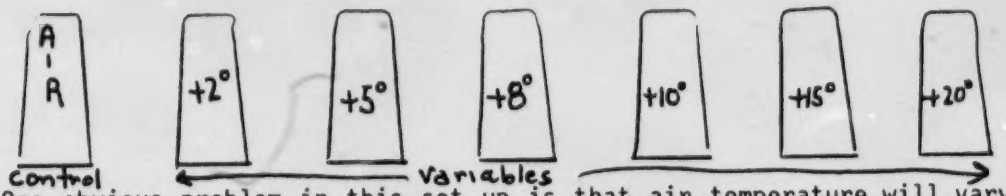
Also of use will be any reasonably good guide to the Algae such as the one published by Brown and Company called How to Know The Freshwater Algae.

LAB D-5 THERMAL POLLUTION

Purpose: To study thermal or heat input into lake systems and to look at possible cures.

Materials: 7 one gallon aquaria, cultures of mixed microorganisms, thermostatically controlled heat sources, readings (see end of lab)

Procedure: Set up the seven aquaria. Take care to place each under the same light conditions. The experiment will have as its variable temperature. The exact latitude for the experiment will be left to the investigator. An appropriate regime might be as follows:



One obvious problem in this set up is that air temperature will vary. The most logical solution might be using "mean" daily temperatures to set the temperature of the control.

Data should be collected on a weekly basis. Data would include enumeration algae, zooplankton, and if equipment permits pH, and various other chemical parameters might be examined. If the same size samples are taken, and the water levels remain the same then the numbers collected will have relative merit. All nomerical determinations should be done under high power (400X).

Noted Organisms	Numbers present on the sampling dates					
	week 1	week 2	week 3	week 4	week 5	week 6

Questions:

1. Is there a variance in total numbers of organisms in the various aquaria? What, if any, is the correlation of these differences and temp.?

2. Is it possible to extrapolate results from this experiment to real heat input situations? If this is done what are the dangers that must be observed?

Questions: (con't)

3. What is the scientific reason for doing all counts under 400 X?

4. What is the possible temperature increase from various electrical generating equipment... fossil, nuclear, etc.?

5. What are some possible uses for heated water?

6. Cooling towers are useful in some instances. What are some advantages and disadvantages of this type of cooling system? (include wet and dry)

Required Readings:

Clark, John R., "Thermal Pollution and Aquatic Life," Sci. Amer. 220:3 pp. 18-27. Offprint 1135.

Carter, Luther J., "Warm Water Irrigation: An answer to Thermal Pollution," Science, Vol. 165, 1 August 1969, pp. 478-480.

Woodson, Riley D., "Cooling Towers," Scientific American, pp. 70-78.

LAB D-6a CHEMICAL EXAMINATION OF WATER

Purpose: To expose students to the concept of chemical tests and to be able to replicate them.

Materials: A water test kit (preferably using a colorimeter like Spec-20 or Hach DL for the chemical tests of NO_3, PO_4, SiO_2, NO_2, NH_3); a test kit for dissolved oxygen (Winkler's method); test kit for alkalinity, pH meter.

Procedure: A general word about procedures is that they will vary according to the test kit and the test. The instruction in the appendix to this lab hold true for the tests that use the Spec-20. The conversion tables given are from the Gull Lake Laboratories and Dr. Robert G. Wetzel. The titametric tests are those commonly used and are listed below - in addition they can be found in Limnological Methods by Welsh. The Handbook of Standard Methods is also a prime source. Any test kit or instrument will have the instructions spelled out and these should be faithfully followed if there is the chance of desired repeatability.

LAB D-6b CHEMICAL EXAMINATION OF WATER---NITRATE AND PHOSPHATE

Purpose: To gain further insight into nitrate and phosphate in the water systems.

Materials and Procedures: Follow the instructions for each specific test that are listed below.

LAB D-7 EUTROPHICATION OF LAKE SYSTEMS

Purpose: To obtain an understanding of the natural process that leads to the ultimate end of the lake as a body of water.

Materials: slides, and film loop showing succession, articles, charts, data

Procedure: Use the visual materials to gain a beginning understanding of the problem once that this has been accomplished it will then involve the detailed study of the charts of lake aging that are given in the attached appendix to this lab. Reading the articles (see resources below) will help to give an insight into the ramnifications of the eutrophication situation.

Questions:

1. Is the process of eutrophication normal?
2. Briefly outline the various chemical changes that occur in an oligotrophic lake as compared to a eutrophic lake.
3. What are the differences between cultural (i.e., man-made) as opposed to natural eutrophication?
4. Does eutrophication totally destroy the productivity of an area? See text.
5. If you were living on a lake and there were algal blooms what would you try to do? Why?
6. What is the effect of aging on the fish production?
7. What are the major differences between pollution and eutrophication?

Resources:

Charts and graphs from the M.S.U. Limnological Studies Area. (see appendix)

"Aging Great Lakes," Powers, C. F., et al, Scientific American, Nov., 1966 (Offprint 1056) W. H. Freeman and Co., San Francisco.

Transparency of Fish Production in Lake Erie (see appendix)

"Lake Succession," a filmloop produced by EBF.

2 x 2 transparencies of lakes in the area showing stages of eutrophication (local)

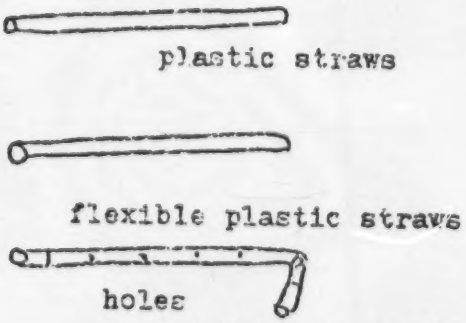
LAB D-9 METHODS OF TREATING SEWAGE WASTES

Purpose: To explore sewage treatment through the use of a model septic tank system.

Materials: ½ gal. cardboard milk carton, quart milk crton, supply of plastic straws, including flexible ones, sand, and water

Procedure: Take the ½ gallon carton and make the cuts as shown in fig. 1. Use the straws and the cartons to set up the system shown in figure 2. Use a water-sand mixture to simulate the sewage.

Fig. 1



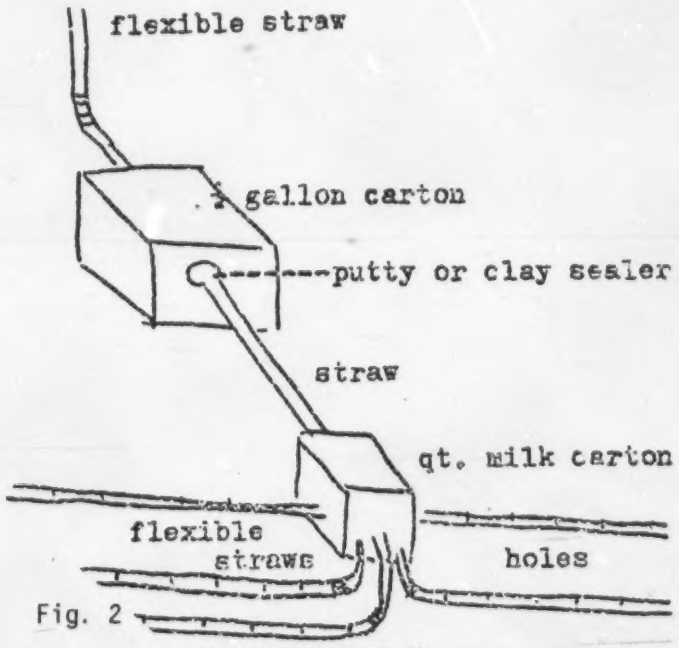


Fig. 2

The model illustrated in fig. 2 will be placed in the ground with gravel in the drain field dtiches.

Questions:

1. What are some problems in using a septic tank system?
2. What is the basis of a septic tank's action?
3. Where do the products of a septic tank's action go?
4. Research to find the difference between a septic tank and the Charlotte-Mecklenburg Sewage Treatment System.

NOTE TO TEACHER: The masters attached to this lab will enable you to effectively help with the last question.

LAB D-10 BOG, SWAMP, MARSH

Purpose: To develop an awareness of dystrophic systems - some dynamic; others in a perpetual recycling valled pulse stablity.

Materials: Reference materials to complete this open-ended lab.

Procedure: using whatever materials are necessary provide an adequate demonstration of the following topics. "Adequate" might include written reports, pictures, slides, modules, etc. It will NOT include any one single media.

1) Define each of the words in the title of this lab.

2) Outline the volution of a bog, swamp, and marsh.

3) Survey typical organisms found in each of the places mentioned in the title.

4) Survey the various chemical changes in the systems.

5) Locate and describe the nearest of each system to Charlotte. A map would be helpful.

NOTE: an example of Cedar Swamp Ecology is included with this lab. This uses only two of the media approaches and would be much better of there several more used.

LAB D-12 LOTIC SYSTEMS

Purpose: To cause students to understand the structure and function of stream ecosystems.

Materials: Article, "STRUCTURE AND FUNCTION OF STREAM ECOSYSTEMS" Kenneth W. Cummins, Bioscience, Nov., 1974, pp. 631-641.

Procedure: Read the article and be responsible for answering the questions in the section below.

Questions:

1) What assumption presents serious problems to understanding stream ecology? Why?

2) What does Cummins call "intriguing features" of temperate woodland ecology?

3) Define the acronyms - POM, DOM, CPOM, FPOM.

4) Explain figure 6 as it relates to topics covered in the Odum article, "Strategies of Ecosystem Development." (Chapter 3)

5) What two groups of photosynthetic organisms exist in a stream?

6) What controls the processing rates of organic matter?

7) With respect to what reference is water quality always defined?

8) What are three general management strategies?

LAB D-13 LINKAGES BETWEEN TERRESTRIAL AND AQUATIC ECOSYSTEMS

Purpose: To acquire insight into the links between terrestrial and aquatic systems.

Materials: Article, "LINKAGES BETWEEN TERRESTRIAL AND QUATIC ECOSYSTEMS," by Gene Likens, Bioscience 24:8. P 447-456.

Procedure: Read the article and be responsible for answering the following questions. After completing the questions devise an experiment to check on the validity of some part of the article.

Questions:

1) List and describe the three transporting mechanisms for energy and materials.

2) What is meant by "uphill" transport? List short and long termopossibilities.

3) What is the pathway(s) for toxic substances to enter the aquatic system?

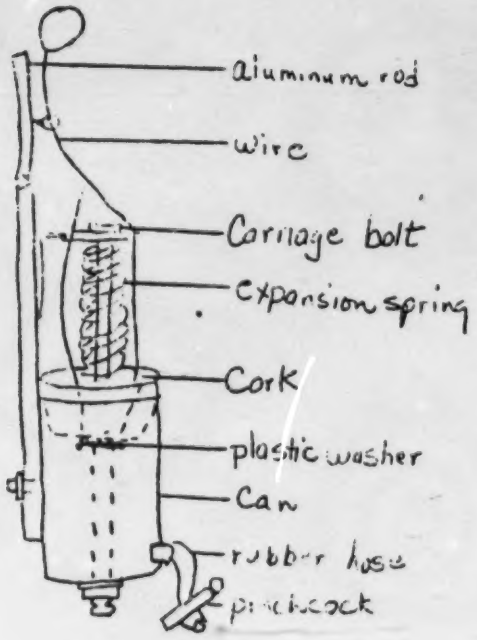
4) Which produces more eroded soil pasture or pine plantation? How do you account for your answer?

5) What is the major phosphorous input to the lake system? The major nitrogen input?

6) What factors affect cultural eutrophication?

7) What can pollutants added to the airshed do to terrestrial and quatic systems?

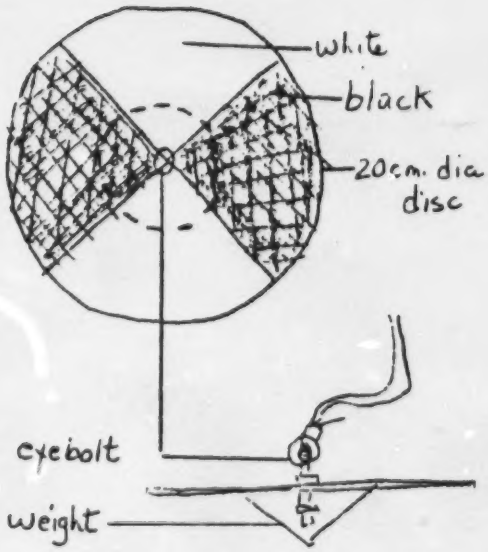
8) What does "assimilation capacity" refer to?



Water Sampling Apparatus

The collection of samples of water from various depths requires some ingenuity. The apparatus that is shown to the left fulfills the need.

If depths are to be sampled that are deeper than the rod a weight may be added to the bottom of the can and use of a weaker spring so as to prevent the apparatus being pulled up when the sample is taken.



Secchi Disc

The construction of a Secchi disc is very easy requiring only those materials shown in the diagram to the left.

Temperature Device

A plastic jug can easily be mae into a device that will tell the temperatures at various depths. To sink the jug it will be necessary to weight it with concrete or rocks. An eyebolt is placed through a cork and then tied to the handle. This arrangement will cause the plug to be pulled at the desired depth. Bring the jug to the surface and let the thermometer remain in it for three minutes.

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Plankton Tow Net

Through the use of a clothes hanger and some nylon a cheap plankton net can be constructed. The wire is bent into shape and the nylon is stitched around the hoop. In the case of lack of nylon fabric hose doubled work well.

Clinometer

The diagram for this follows full instructions are on the following pages